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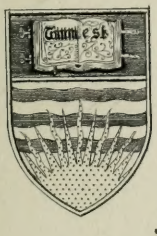

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Canadian Institute of Mining and Metallurgy

THE TRANSACTIONS

OF THE

Canadian Mining Institute

1912

Presented to the University of British Columbia by his mother, in memory of the late Captain O. E. LeRoy.

Captain LeRoy was commander of "D" British Columbia Company 196th Battalion, Western Universities C.E.F., and died of wounds received at Passchendaele, Flanders, October 28th, 1917.

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DR. ALFRED E. BARLOW

President, Canadian Mining Institute, March, 1912 to March, 1913

CANADIAN MINING INSTITUTE

List of Officers and Members of Council since the Establishment of the Institute, showing the years during which office has been held.

PRESIDENT.

Adams, F. D., 1910, 1911.
Barlow, Alfred E., 1912.
Coste, Eugene, 1903, 1904.
Fergie, Charles, 1901, 1902.
Fowler, S. S., 1900.
Hardman, J. E., 1898-99.
Keffer, Frederic, 1907.
Miller, W. G., 1908, 1909.
Smith, G. R., 1905, 1906.

VICE-PRESIDENT.

Adams, F. D., 1901, 1902, 1903, 1905, 1906.
Barlow, A. E., 1908, 1909, 1910, 1911.
Blue, John, 1898-99.
Cantley, Thomas, 1905, 1911, 1912.
Carlyle, W. A., 1898-99.
Chambers, R. E., 1903, 1904.
Cole, Arthur A., 1912.
Coste, Eugene, 1902.
Dawson, G. M., C.M.G., 1898-99.
Donkin, Hiram, 1899, 1900.
Drummond, Geo. E., 1899, 1900, 1908, 1909.
Duggan, G. H., 1905, 1906, 1907.
Fergie, Chas., 1898, 1899, 1900.
Fraser, Graham, 1901, 1902.
Goodwin, W. L., 1905.
Hedley, R. R., 1901, 1902.
Hobson, J. B., 1903, 1904.
Hodges, A. B. W., 1910, 1911.
Keffer, F., 1905, 1906.
Kirby, E. B., 1904.
Leckie, R. G., 1905, 1906.
Leonard, R. W., 1910, 1911.
Lindsey, G. G. S., 1912.
McArthur, James, 1900, 1901.
Miller, W. G., 1907.
Obalski, J., 1909, 1910.
Porter, J. Bonsall, 1907, 1908. 1908.
Robertson, W. F., 1907, 1908, 1909.
Smith, G. R., 1903, 1904.
Stewart, R. H., 1912.

COUNCILLORS.

Adams, F. D., 1899, 1900, 1904, 1907, 1908.
Aldridge, W. H., 1905, 1906, 1907.
Bancroft, J. A., 1911, 1912.
Barlow, A. E., 1905, 1906, 1907. 1907.
Bennett, B., 1902, 1903.
Blakemore, Wm., 1898-9.
Blaylock, S. G., 1910, 1911.
Blue, Archibald, 1898-9.
Blue, John, 1905, 1906.
Brent, Charles, 1899, 1900.
Brewer, Wm. W., 1908, 1909.
Brigstocke, R. W., 1909, 1910, 1911, 1912.
Brock, R. W., 1907, 1908, 1909, 1910, 1911.
Brown, J. Stevenson, 1909, 1910.
Browne, David H., 1907, 1908.
Bryce, R. A., 1910, 1911.
Cantley, T., 1903, 1904, 1905, 1906-1909, 1910.
Chambers, R. E., 1901, 1902.
Cirkel, F., 1904.
Cole, Arthur A., 1908, 1909, 1910, 1911.
Coll, C. J., 1905, 1906, 1909, 1910.
Corkill, E. T., 1911, 1912.
Coste, Eugene, 1899, 1900.
Coulthard, R. W., 1912.
Cowans, J. R., 1899, 1900.
Craig, B. A. C., 1905, 1906, 1907.
DeKalb, Courtenay, 1901, 1902.
Denis, Theo., 1911, 1912.
DePencier, H. P., 1912.
Dimock, C., 1898-9.
Donkin, H., 1898-9.
Donnelly, J., 1909, 1910, 1911, 1912.
Dowling, D. B., 1912.
Dresser, J. A., 1910, 1911.

COUNCILLORS—Continued

DRUMMOND, GEO. E., 1898-9.
DRURY, H. A., 1908, 1909.
DUGGAN, G. H., 1903, 1904, 1912.
DULIEUX, E., 1911, 1912.
FERGIE, CHAS., 1908, 1909, 1910, 1911, 1912.
FERRIER, W. F., 1912.
FOWLER, S. S., 1898, 1899.
FRALECK, E. L., 1909.
FRASER, GRAHAM, 1904.
GALT, E. T., 1899, 1900.
GILMAN, E. W., 1907, 1908.
GILPIN, E., 1903, 1904.
GOODWIN, W. L., 1903, 1904.
GRAY, F. W., 1911, 1912.
GWILLIM, J. C., 1905, 1906, 1907, 1908.
HARDMAN, JOHN E., 1908, 1909.
HAULTAIN, H. E. T., 1907, 1908, 1909, 1910.
HAY, A. M., 1905, 1906, 1907.
HEDLEY, ROBT. R., 1900, 1905, 1912.
HERSEY, M. L., 1909, 1910.
HOBSON, J. B,. 1898, 1899, 1901, 1902.
HODGES, A. B. W., 1909.
HOPPER, R. T., 1899, 1900, 1905, 1906, 1907, 1908, 1909, 1910, 1911.
JOHNSON, WM. S., 1912.
KEFFER, FREDERIC, 1902, 1903.
KERR, D. G., 1903, 1904.
KIRBY, E. B., 1900, 1901, 1903.
KIDDIE, THOS., 1905, 1906, 1907.
KIRKEGAARD, P., 1901, 1902.
LECKIE, R. G., 1898-9, 1901, 1904.
LEWIS, JAMES F., 1900, 1901.
LIBBY, W. L., 1898-9, 1902.
LINDSEY, G. G. S., 1910, 1911.
LITTLE, W. F., 1901, 1902.
LORING, FRANK C., 1898-9.
MACDONALD, BERNARD, 1900, 1901.
MCARTHUR, JAMES, 1898-9.
MCCALL, J. T., 1901, 1902.
MCCONNELL, R. G., 1900, 1901.
MCEVOY, J. 1904, 1905, 1906, 1907, 1908, 1910, 1911.
MCNAB, A. J., 1908, 1909.
MCNAUGHTON, G. F., 1900, 1901.
MEISSENER, C. A., 1899, 1900, 1905.
MERRITT, W. HAMILTON, 1898-9.
MILLER, W. G., 1904, 1905, 1906. 1906.
OBALSKI, J., 1898, 1905.
PARRISH, S. F., 1903, 1904.
PARSONS, W. F. C., 1908.
PENHALE, J. J., 1898-9, 1910, 1911, 1912.
POOLE, H. S., 1900, 1901.
PORTER, J. BONSALL, 1902, 1903, 1905, 1906, 1909, 1910.
ROBB, D. W., 1901, 1902, 1905, 1906, 1907, 1908.
ROBBINS, FRANK, 1902.
ROBERTSON, W. F., 1904.
SHIELDS, CORNELIUS, 1902, 1903.
SILVESTER, G. E., 1911, 1912.
SJOSTEDT, E. A., 1902, 1903.
SMITH, F. B., 1905, 1906, 1907, 1908.
SMITH, GEO. R., 1898-9, 1901, 1902.
SMITH, J. BURLEY, 1900, 1901.
SMITH, O. B., 1908, 1909.
SNYDER, F. T., 1898-9.
STEWART, R. H., 1908, 1909.
TONKIN, J. H., 1903.
TURNER, A. P., 1902, 1903.
TYRRELL, J. B., 1908, 1909, 1910, 1911, 1912.
WATSON, C. E., 1912.
WHITESIDE, O E. S., 1910, 1911.
WILLIAMS, H. J., 1903, 1904, 1905, 1906.
WILLMOTT, A. B., 1905.

SECRETARY.

BELL, B. T. A., 1898, 1899, 1900, 1901, 1902, 1903.
COSTE, EUGENE (Acting Secretary), 1904.
LAMB, H. MORTIMER, 1905, 1906, 1907, 1908, 1909, 1910, 1911, 1912.

TREASURER.

BROWN, J. STEVENSON, 1900, 1901, 1902, 1903, 1904, 1905, 1906, 1907, 1908.
LAMB, H. MORTIMER, 1911, 1912.
LECKY, W. S., 1909, 1910.
STEVENSON, A. W., 1898, 1899.

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MEETINGS

PROCEEDINGS OF THE FOURTEENTH ANNUAL MEETING.

TORONTO, MARCH 6, 7 AND 8, 1912.

The Fourteenth Annual General Meeting of the Institute was held in the King Edward Hotel, Toronto, on Wednesday, Thursday and Friday, March 6th, 7th and 8th, 1912, the President, Dr. Frank D. Adams, in the chair. The attendance was two hundred and seventy-four, or rather over twenty-five per cent. of the total membership. Among the invited guests were: Mr. J. Parke Channing and Dr. W. H. Tolman, of New York; Mr. T. A. Rickard, of London, England, representing the Institution of Mining and Metallurgy; Dr. J. F. Kemp, Mr. F. L. Garrison, Mr. R. V. Norris, Mr. Theodore Dwight, Prof. Robt. H. Richards, Mr. W. E. C. Eustis, Mr. W. Kelly, Mr. J. Birkinbine, and Mr. C. R. Corning, honorary delegates representing the American Institutes of Mining Engineers; Mr. F. H. Sexton, representing the Mining Society of Nova Scotia; and Mr. R. R. Hedley, chairman, and Mr. E. Jacobs, secretary, of the Western Branch of the Institute.

WEDNESDAY MORNING SESSION.

The members assembled in the Ball Room of the King Edward Hotel, at 10 a.m. and were welcomed by the Hon. William H. Hearst, Minister of Lands, Forests and Mines of the Province of Ontario, who spoke as follows:

"MR. PRESIDENT AND GENTLEMEN: It affords me very great pleasure on behalf of the banner Province of the Dominion and of the banner city of that Province to welcome you on this occasion.

"As a mineral producing territory, Ontario has but made a beginning; nevertheless, the advancement during the past five or six years has been eminently gratifying. Our mineral output has doubled, almost trebled within this period, and we at least may be proud of the fact that Ontario now produces no less than one-seventh of the world's total annual production of silver. Our pre-eminence in respect of nickel production scarcely needs reiteration.

"It may, however, be interesting to point out that here there is still a vast virgin territory awaiting the attention of the prospector—a region of great mineral potentialities. The Province of Ontario contains some 140,000,000 acres of land; but so far only 24,000,000 acres have been alienated from the Crown; while a further hundred million acres of territory will be shortly added to the area of the Province.

"I have but recently assumed the duties that pertain to the position of Minister of Lands and Mines of the Province of Ontario. Before I accepted office I realized to some extent its responsibilities. To-day I have a greater realization and understanding of these responsibilities and a more thorough appreciation of the great work to be undertaken and accomplished. It will be my earnest aim by wise and well-considered measures to promote and foster the welfare of the mineral industry, and thereby follow in the footsteps of my predecessor. Herein I seek your advice, your co-operation and your support."

MESSAGE FROM H.R.H. THE GOVERNOR-GENERAL.

The Secretary then read the following message from H.R.H. The Duke of Connaught, Governor-General of Canada:

"As patron of the Canadian Mining Institute I desire to convey to all the members of the Institute at the Annual Meeting my best wishes and regrets that I cannot be present in person.

"I congratulate them on their success in the past, and trust that the future may continue to afford them the reward which they so richly deserve for their efforts in the development of the riches of their country, their application of the teaching of science, and their courageous enterprise and confidence in the mineral resources of Canada."

PRESIDENTIAL ADDRESS.

The President then presented his annual address as under:

"It is a great pleasure for me at the opening of this, the Fourteenth Annual Meeting of the Canadian Mining Institute, to be able to record the continued prosperity of the mining indus-

try of the Dominion and a substantial growth in the work and influence of the Canadian Mining Institute.

Activities of the Institute.—"The policy of establishing branches of the Institute, inaugurated in the year 1902 with the view to maintaining the interest in the work of the Institute in localities remote from headquarters, and which has proved so successful in the past, has been continued, and during the past year two new branches, at Sudbury and Porcupine respectively, have been established with every prospect of a vigorous and useful career. At the meeting for the organization of the Porcupine branch there was an attendance of one hundred and six.

"The Council has also arranged, with the hearty support of the western members of the Institute, to hold semi-annual meetings in the West in future, and thus enable members there who are unable, by reason of distance, to attend the regular annual meeting held in Eastern Canada to participate more actively in the work of the Institute. The first of these meetings will be held during the coming summer.

"Among the more important undertakings in which the Institute has been engaged during the past year was drafting, at the request of the Federal Government, of a code of mining laws for that portion of Canada in which the minerals are still under Federal control. A Bill, embodying this code and based on the principles advocated by the Institute, is now ready for submission to Parliament. The thanks of the Institute are especially due to Messrs. G. G. S. Lindsey, R. W. Brock and F. T. Congdon, M.P., for their services in connection with this very important work.

"It may here be mentioned that the membership of the Institue has increased during the past two years from 850 to 945.

The Mineral Industry.—"The mineral output of the Dominion for the past year (1911) shows a slight falling off as compared with the output of 1910, although it is much larger than that of any former year in the history of the Dominion. This decrease is chiefly due to the suspension of coal mining in the west, because of the strike of the coal mine-employees in Alberta and British Columbia, which strike was continued for the greater part of the year and affected not only the output of

coal in those Provinces, but also seriously curtailed the output of the copper smelters. The Provincial Mineralologist of British Columbia estimates that as an immediate consequence of the labour difficulties in the Crow's Nest Collieries, there was a decrease of at least $4,500,000 in the mineral output of this Province. The mineral output of both Ontario and Quebec shows a marked increase. There is, moreover, a marked increase in the value of the structural materials produced in the Dominion during the past year, indicating a rapid development of constructional work and general building operations in the country.

"The effect of the growth of the mineral industry in Canada during the past few years is being felt in all departments of our national life. New towns are springing up whose existence is due entirely to the development of our mining areas, and in Canada the experience of other countries, namely, that the development of mining areas is followed by the extensive development and settlement of new and remote districts, is being repeated in our own. Thus, to take one district in Ontario as an example, as the result of the mining development in the Sudbury, Cobalt and Porcupine areas, not only have Copper Cliff, Cobalt, South Porcupine and other towns come into being, but the railway system of Northern Ontario is being largely extended, and the Ontario Government has just set aside the large sum of $5,000,000 to be devoted to the agricultural development of the great clay belt of New Ontario, an area that but for the discovery of mineral deposits would have remained a wilderness for long years to come. This, in its turn, contributes to the development of the trade of our great manufacturing and distributing centres.

The Relation of Geology to Mining.—"As the Institute has honoured me by electing me, a geologist, to be its President during the past two years, it has occurred to me that in bringing my very pleasant labours to a close during the present session, I might invite your attention for a few moments, at this time, to the very important rôle which, in recent years, geology has come to play in relation to mining; to the services which the science of geology has rendered to the art of mining; and to the services which have been rendered by the geologists of Canada

to the development of mining in our Dominion. And, first, it is of interest in this connection to note that mining was carried on long before the rise of the science of geology. The discovery of the art of mining and smelting certain metals takes us back to the bronze age, which long antedates the dawn of written history. In certain favoured localities on the earth's surface peculiar kinds of stone were found which, under the influence of fire, yielded those wonderful metallic substances on whose possession our civilization is so largely based. These stones were dug wherever they were found, and the primeval forest supplied the fuel for their reduction. As the deposits ran down into the earth's crust it was necessary to follow them, and the art of breaking them up by fire, with the aid of such rude tools as were in man's possession before the discovery of steel, and that of supporting the walls and roofs of the excavations from which the ores were taken, gradually developed the Art of Mining.

"As has been shown by Alfred H. Brooks in an admirable paper recently presented to the Washington Academy of Sciences, it was not until the later part of the 18th century that any definite idea of the structure of the earth's crust and the relation of its mineral deposits to this structure commenced to be entertained. The recognition of the fact that such a connection existed was due largely to the work of Werner, professor of the older science of Mineralogy at Freiberg. At the Mining Academy at Frieberg, established in 1765, mining was taught, as Brooks remarks, twenty years before the existence of any other school of engineering except those devoted to military sciences. The founding of the Mining Academy at Freiberg indicated that the time had come when mining was to be carried on by mining engineers and not by artisans.

"Werner was the first great teacher of the science of Geology, and his work entitled 'Neue Theorie von der Entstehung der Gänge' was the first of that series of treatises on the ore deposits which have appeared since Werner's time and more especially in recent years. After Werner no one gave so marked an impetus to the study of geology by showing its immense economic value as William Smith, the 'Father of English Geology,' who first pointed out the relation of coal beds to the associated

strata, worked out the greater part of the stratigraphic succession in England, and discovered the very important fact that every formation can be recognized by certain fossils which are characteristic of it. It was the work of William Smith that led to the widespread recognition in English-speaking countries of the immense importance of the study of economic geology. When the British 'adventurer' in coal lands came to recognize that one could distinguish the Old Red Sandstone—below which there was no coal—from the New Red Sandstone beneath which the coal measures lay, by a simple inspection of its fossil remains, Palaeontology came to interest him deeply, for it touched his pocket. This led to the establishment of the Geological Survey of Great Britain in 1835 for the systematic study of the geological structure and mineral resources of the British Isles.

"This was followed by the establishment of similar surveys in other countries; and so widespread has become the recognition of the economic value of geology at the present day that there is now scarcely a civilized country in the world that has not a regularly constituted Geological Survey. Of the one hundred and fourteen countries with which the Executive of the Twelfth International Geological Congress is now in communication, no less than sixty-six—or fifty-eight per cent.—have such surveys. These include nearly all the leading nations of the world, and those without such surveys are chiefly the less civilized countries or minor dependencies of the greater States, concerning whose mineral resources but little is at present known.

"Furthermore, as time goes on, geology is, year by year, touching a wider range of subjects in its economic application. Of the thirteen hundred reports and papers on geology published in North America in the year 1909, six hundred dealt with applied geology; and a study of the publications of the Geological Survey of the United States shows that, while in 1890 less than one per cent. of the publications issued by its Survey treated of applied geology, in 1910 the percentage had risen to ninety-eight. This increasing application of the science of geology to the practical needs of man is not peculiar to the United States, but is seen in many widely separated countries. Every-

where the study of practical geology is making its value felt and is receiving increased support, both publicly and privately.

"Everywhere also we find the national governments looking to their Geological Surveys for the solution of many pressing problems. When the Government of the United States recently wished to take stock of the mineral resources of the national domain, it entrusted the work of making such an inventory to its Geological Survey; or when on account of restrictive legislation in Germany its supplies of potash were threatened, it instructed its Federal Survey to make a search for supplies of potash in the United States and gave the Survey a special appropriation for this purpose. Or, again, when the Japanese Government wished to obtain an accurate knowledge of the value of the economic resources, actual and potential, of Korea, a geological survey of the peninsula was ordered and carried out by the government geologists of Japan during the war with Russia.

"But it is not only in his relation to the Government service that the value of the geologist is coming to be recognized, for now nearly every large mining company and many of the great railways have one or more geologists on their staff. A large and ever-increasing number of geologists, furthermore, are engaged in private practice; in fact, the demand from these sources for the services of the economic geologist has made it very difficult and often impossible for the Government Bureaus to retain the services of their best men.

"From a multitude of instances where the geologist has rendered signal service to the mining industry, the following may be specially mentioned: The working out of the structure and mode of occurrence of the great iron ore deposits of the Lake Superior region by the geologists of the United States Survey, as well as the geologists of the United States Steel Corporation and those of the several private companies operating in this district. This work has not only led to a thorough understanding of the size, position, form and mode of occurrence of the ore bodies, but a knowledge of the geological structure of the district has led to the prediction of the existence of new ore bodies in certain hitherto unsuspected places, which upon devel-

opment of the respective areas have been discovered. The working out of the structure of the several great iron ore fields of Clinton age, and the determination of the position and shape of the ore bodies, and the amount of the reserves. The discovery of the significance of the anticlinal structure in the case of many of the great oil and gas fields, leading to the discovery of large supplies of these natural products in localities where they were not formerly supposed to exist. The discovery of a new coal field in Kent, due exclusively to the predictions of its existence beneath overlying formations based on a study of the geological structure of the south of England. The development of our knowledge of the whole subject of artesian wells and underground water supplies, which have not only been of inestimable value in many settled countries, but have resulted in the reclaiming of great areas of desert land in many parts of the world, which have been made available for the use of man and which now support large agricultural populations.

"But let us turn our attention for a few minutes to the services which geology has rendered to the development of our own Dominion. The immediate cause which led to the establishment of the Geological Survey of Canada was the wish on the part of the Government to have certain questions relating to the mineral deposits of the country investigated by properly qualified persons.

"Mr., afterwards Sir, William Logan, was appointed the first director, and one of his first tasks was the examination of the supposed oil field in the Gaspe Peninsula. From the time of his appointment to the time of his retirement Logan, while by no means neglecting the study of the scientific aspects of Canadian geology, made economic geology his chief study, and his work, as universally acknowledged, was of immense service in the development of the country. His 'Geology of Canada' is a classic, containing wealth of information concerning the mineral resources of Canada, as the country was at that time constituted. Among his services was the working out of the distribution and succession of the older crystalline rocks of Eastern Canada. He discovered, and mapped the distribution of the Huronian series, pointed out its mineral-bearing character and

showed that the area underlain by it was especially worthy of careful prospecting for metallic minerals. The correctness of his opinion in this respect has been borne out by the discovery of the Sudbury, Cobalt, Porcupine and other great ore deposits, all on the 'original Huronian' belt, and by the fact that wherever these Huronian areas have been carefully examined they have proved to be more or less highly mineralized.

"On the other hand, Logan's studies of the geology of Canada enabled him to point out that it was useless to search for certain minerals in certain areas or districts. His statement that there was 'no coal in Canada' was counted a hard saying at the time, but it prevented the waste of an immense amount of money. And it is a generalization which has been remarkably correct, for in the Canada of Logan's day (which included only the Provinces of Ontario and Quebec) no true coal had ever been found, and the only substances which have been discovered and which approach coal in character is a deposit of anthraxolite of no commercial value found in the Sudbury district, and a deposit of peaty-lignite found in the drift overlying the ancient crystalline rocks in the Missinaibi district towards the shore of James Bay.

"The numerous reports and other publications by Logan's successors—Selwyn and Dawson—contributed in no small measure to the development of our Prairie Provinces. Before the Geological Survey entered upon its work in the west, the only known outcrop of coal was at Lethbridge. As a result of a study of the structure of this area, the Survey demonstrated the wide distribution of coal at no great depth below the surface in the western portion of the great plains, and the work of the Survey in more recent times by Dowling and others has led to the discovery of additional great areas of coal in the west, among which may be mentioned the Brazeau field which Dowling discovered in 1906 and into which, at the present time, three lines of railway are being built. The coal deposits of the White Horse district were also discovered by Mr. Cairnes of the Geological Survey.

"The older prospectors in West Kootenay attributed the finding of the rich ores of the Slocan district to Dr. Dawson;

for after the discovery of the Copper Queen near Nelson, Dawson advised the prospectors to work on northward around the edge of the Nelson granite, and as a result the Slocan was found. Subsequently the recognition of argentiferous tetrahedrite as one of the first formed minerals of the lead ores of the Lardeau enabled the Survey to recommend deep development in that region, which has been followed with excellent results.

"Dr. W. G. Miller, Provincial Geologist of Ontario, discovered the silver ores of the Cobalt camp and gave the prospectors a geological map of the area and a clear account of the geology, which was of the greatest value to them.

"Time will not permit to continue the enumeration of instances where the work of the geologist has been of signal value in the discovery and development of the mineral resources of the Dominion. The above are merely a few selected from many.

"The geologists of the Dominion have also been of service to the community in very many cases in that they have pointed out what should *not* be done. They have saved enormous sums in the aggregate by pointing out in advance that certain exploratory work or proposed expeditions would lead to no result. Many instances of this kind of service could be mentioned by any geologist. I have in mind a case where formerly a mining company operating in the Province of Quebec, spent large sums of money in boring through a solid slate formation in the expectation of reaching alluvial gold deposits. They probably employed a practical gold miner from California, who had seen shafts sunk in certain parts of that State through the Tertiary lavas (which there have flowed over the alluvial deposits) to rich alluvial gravels beneath; but the company, having neglected to consult a man having sufficient knowledge of geology to distinguish a dark lava from a dark slate, they were involved in a large expenditure, which might have been avoided.

"But apart from and in addition to these direct and immediate contributions to the advantage of the mining industry, we owe almost exclusively to the exploratory work of the Geological Survey of Canada our knowledge of the more remote and inaccessible parts of our Dominion, and its work indicates those portions of our hinterland which are especially worthy of attention

on the part of the prospector and the capitalist interested in mining. It applies the knowledge gained from a study of the southern portion of Canada to the great northern portion of our land into which settlement is steadily and continuously forcing its way, and if his directions are heeded, the geologist will be of even greater service in northern Canada than he has been in the south, for he has now the accumulated experience of years in Canadian geology on which to base his opinions.

"One of the most important services rendered by the geologist, whether connected with one of the official surveys or in his private capacity, is in guiding the work of prospectors by pointing out mineralized districts which afford promising ground for prospecting and detailed study and in furnishing geological maps and information with reference to the geological conditions under which certain minerals occur. And a second is by furnishing the companies opening up new areas of valuable minerals, information with reference to the structure of the respective areas, the mode of occurrence and origin of the ore bodies, thus aiding in the development of the mines.

"The large number of very highly appreciative letters now on file in the office of the Geological Survey of Canada from the great mining companies of the Dominion proves how highly such aid has been appreciated and lead us to the firm belief that in the future the geologists of Canada will exert an influence of ever-increasing value and efficiency in the development of the Mineral Resources of the Dominion of Canada."

PROPOSED AMENDMENTS TO THE BY-LAWS.

Amendments to sections 4, 5, 6 and 7 of the By-laws, proposed by Mr. JAMES MCEVOY, and to sections 33, 34 and 35, proposed by Mr. W. F. FERRIER, were next considered. The President ruled, however, that the motions were not in order, since, in his opinion, the notice as given was insufficient.

At the suggestion of Mr. G. G. S. Lindsey the following gentlemen, namely, Messrs. W. F. FERRIER, J. J. PENHALE, H. E. T. HAULTAIN, J. MCEVOY and R. R. HEDLEY, were appointed a committee to submit a report to the meeting on the amendments

as proposed, which report might, if acceptable, be allowed to stand as a notice of motion preparatory to the introduction of the amendments for debate at the next annual meeting of the Institute.

The Committee subsequently presented the following report:

"Your Committee beg to report that they are unanimously in favour of the amendments to sections 33 and 34 of the By-laws, as proposed by Mr. W. F. FERRIER, with two minor changes. The amendments will now read as follows:

33. The Annual Meeting each year shall appoint a Nominating Committee constituted as follows:

(a) The Chairman of each recognized branch having twenty or more members in good standing;

(b) One member for each of the provinces having twenty or more members in good standing; and one additional member representative of the membership at large. This member shall be a member of Council residing at headquarters.

33a. The Secretary shall act as convenor of the Nomination Committee. The Committee shall prepare and submit to the Secretary the 1st of nominations of persons to all offices falling vacant at the end of the next Annual Meeting; copies of this list (which is not a ballot), shall be sent by the Secretary to all members not less than ninety days prior to the Annual Meeting. It shall be the duty of the Committee to nominate at least fifty per cent. more candidates as Councillors for each geographical division than there are vacancies. Independent nominations signed by not less than ten members of the Institute in good standing may also be submitted to the Secretary not less than sixty days prior to the Annual Meeting.

33b. The Secretary shall prepare a single ballot slip containing all nominations made as above, arranged alphabetically, as hereafter specified, and shall send it to all members not more than thirty-five nor less than thirty days prior to the Annual Meeting. This ballot shall be the sole ballot used in the elections. This ballot shall be so designed as to seal and to provide for the signature of the voter on a coupon, which shall be detached before opening the ballots. The ballot should be enclosed in an envelope addressed to the Secretary.

34. After 1912, of the twenty Councillors, two shall represent the Maritime Provinces, six the Province of Quebec, six the Province of Ontario, and four the provinces west of Ontario, to be called in the ballot, the Western Provinces. One shall be an officer of the Department of Mines of the Dominion Government, and the remaining member shall be the candidate receiving the highest number of votes after the other vacancies have been filled.

Your Committee, therefore, recommend that the discussion of these amendments be deferred until the next Annual Meeting; and that the Secretary issue, well in advance thereof, printed copies of these amendments for the information of members."

A motion was made by Dr. J. B. Porter, seconded by Mr. H. P. DePencier, that this Committee consider and report on the advisability of inserting a clause in the By-laws providing for voting by means of proxies on future amendments to the Constitution and By-laws. Mr. FERRIER, Chairman of the Committee, reported that after due consideration, the Committee was not in favour of the use of proxies at meetings of the Institute; and he, therefore, moved, seconded by Mr. HEDLEY, that proxies be not used at meetings of the Canadian Mining Institute. The motion carried.

On motion of Mr. R. W. BRIGSTOCKE, seconded by Mr. JAMES MCEVOY, the Report of Council for the year ending December 31st, 1911, was received and adopted.

REPORT OF COUNCIL FOR THE YEAR 1911.

The Council have much pleasure in submitting their report of the work of the Institute for the year ending December 31st, 1911; and by way of preface thereto take occasion to congratulate the membership in general on their active interest and co-operation in forwarding the aims and objects of the association, and to which its present satisfactory status and flourishing condition is to so large a degree attributable.

Meetings.—It is generally conceded that the meetings of the Institute are, in point of attendance and enthusiasm, comparable with those of much larger societies of a like purpose and organization. The Annual Meeting in Quebec in March last was no exception to this rule, being in fact, one of the most successful of the annual series to date. In the West, three well-attended meetings have been held under the auspices of the Western Branch, that at New Denver in September being especially noteworthy in this respect. At another meeting of the Western Branch at Trail, B.C., in May, the proposal of the Council to provide in future for regular semi-annual general meetings of the Institute in the West was unanimously endorsed, and the Council consequently hope to arrange for an inaugural meeting during the autumn of the present year (1912). Other Branch meetings have been held in Montreal, Toronto, Cobalt,

Sudbury, and Porcupine. Seven meetings of Council have been held during the year.

Branches.—Two new branches have been successfully organized, the one at Sudbury and the other at Porcupine. The organization meetings in each case were representative and enthusiastic. It is worthy of note that at the Porcupine meeting held on December 16th, the attendance was one hundred and six, including the resident mining engineers and mine managers and a number of visiting members from Montreal, Toronto and Cobalt.

Publications.—A special effort has been made to attain to a still higher standard in the publication of the Institute's Transactions, and to that end some additional expense has been incurred for the provision of a better grade of paper, and for more careful press-work, more particularly in connection with the printing of the half-tone illustrations. The Institute has published during the year five issues of the Bulletin, comprising 875 pages of printed matter; Volume XIV. of the Journal, now in press, will contain 750 pages. The Secretary is preparing a General Index to the Transactions of the Federated Canadian Mining Institute and to Volumes I. to IX. inclusive of the Journal of the Canadian Mining Institute. This index, it is expected, will be published during the coming summer.

Membership.—The membership now numbers, inclusive of all classes: 945.

The accessions during the year were as follows:

Members	68
Associates	21
Students	4
Total	93

The losses by death, resignations and removal were as follows:

Deaths	9
Resignations	24
Removals	48
Total	81

Library and Reading Room.—The accessions to the library number 144 volumes. These have been bound and added to the shelves. Non-resident members have taken advantage freely of the provision enabling them to borrow books from the library for stipulated periods.

Students' Competition and Awards.—Nine papers were submitted by student members in competition for the Insitute's awards. The President's Gold Medal and the first prize of twenty-five dollars were won by Mr. W. L. Uglow, of the School of Mining, Kingston, for his paper entitled, the "Alexo Mine." The second prize of twenty dollars was awarded to Mr. E. B. Davis, of the School of Mining, Kingston, for his paper entitled "The Character and Possible Origin of the Green Dolomites of New Ontario." On the recommendation of the Publication Committee, the prize-winning papers have been published in the Transactions.

Federal Mines Act.—As reported last year, the Institute was successful in inducing the late Government to take preliminary action towards the adoption of a mining law for the Dominion; and in this regard the Council desires to place on record its appreciation of the services rendered by Mr. G. G. S. Lindsey, Chairman of the Committee, who presented the case to the Prime Minister on behalf of the Institute, and, in general, is responsible for advancing the business to its present stage. A draft of a Bill, based on principles advocated by the Institute, was duly prepared. This draft was carefully revised by Mr. F. T. Congdon, M.P., and Mr. R. W. Brock, Director of the Geological Survey, and re-submitted to the Institute's Committee for final approval. It was designed that the Bill should be presented to Parliament at last summer's Session; but unfortunately other business deemed to be more pressing was given precedence. Meanwhile, the attention of the present administration has been called to the requirements in this direction, and it is hoped that the Bill will be made law during the present session of Parliament.

Deputations.—During the month of December a deputation representing the Institute waited on the Right Hon. the Prime Minister to place before him its views as repeatedly expressed

with respect to (1) the appointment of a Minister of Mines for the Dominion; (2) the organization of the Department of Mines, with a view to an increased efficiency in this branch of the public service; and (3) the appointment of a Deputy Minister of Mines.

The deputation also called attention to the fact that the International Congress of Geologists had accepted an invitation to meet in Canada during the year 1913, and the support and co-operation of the Government were asked in the arrangements now being made for the meeting in question.

The deputation was most courteously received and the Prime Minister undertook to give its recommendations very earnest consideration.

(Signed) H. MORTIMER-LAMB,
Secretary.

FINANCIAL STATEMENT.

Receipts and Disbursements for the Year Ending 31st December, 1911.

RECEIPTS.

Cash in Bank, Jan. 1st, 1911		$ 3,935.64
Subscriptions—		
Annual	$6,035.00	
Life	100.00	
Students'	174.00	
Advance	10.00	
Arrears collected	1,085.00	
		7,404.00
Publications—		
Sales	190.00	
Advertisements	552.50	
Binding	183.00	
		925.50
Grants—		
Dominion Govt.	3,000.00	
Quebec Govt.	500.00	
		3,500.00

Miscellaneous—			
Sale of Buttons	18.60		
Sale of Furniture ..	15.00		
A. C. Lane, Prize	15.00		
Interest	396.50		
		445.10	12,274.60
			$16,210.24

DISBURSEMENTS.

Publications—			
Printing, Binding & Distributing Vol. XIII (part).	1,578.22		
Printing Vol. XIV (part)	1,129.76		
Engravings Vol. XIV (part)	244.17		
Postage, Express Packing, Distributing, etc.	393.61		
Printing, By-Laws & Membership List ..	125.00		
Prizes to Students...	45.00		
Editor's Salary	1,600.00		
		5,115.76	
Meetings—			
Annual Meetings	463.56		
Council Meetings	56.00		
		519.56	
Secretary's Office—			
Salaries of Staff 3,335.50			
Less: Chargeable to Publications 1,600.00		1,735.50	
Rent		750.00	
Telephones & Telegrams		89.15	

Postages	149.70		
Printing & Stationery	328.56		
Audit	60.00		
Insurance	41.00		
Travelling Expenses ..	621.55		
Legal Expenses	5.00		
Service & Incidentals.	54.30		
Purchase of Institute. Buttons	43.80		
Advertising	50.00		
Bank Charges	28.25		
		3,936.81	
Library—			
Books Purchased	94.91		
Binding (part 1910 & 1911)	189.95		
Furniture	67.65		
		352.51	
Branches—			
Western Branch	351.00		
Sudbury Branch (organization, &c.) ..	14.85		
		365.85	
			10,290.49
Balance in Bank			5,919.75
Less: estimated to complete Vol. XIV.			1,300.00
			$ 4,619.75

(Signed) H. MORTIMER-LAMB,
Treasurer.

AUDITORS' REPORT.

"We beg to report having completed the audit of the financial books of your Institute for the year ended 31st December, 1911.

"The monies received on account of the Institute have been verified by checking stubs of the Receipt Books to the Cash Book. The amounts received have been regularly deposited in the Bank Account and the disbursements have been made by cheque and are covered by duly approved vouchers.

"The additions of the subsidiary books and the posting of the entries therein to the various Ledger Accounts have been checked in detail and we have seen that they were correctly incorporated in the Financial statements for the year.

"The balance in the Bank Account at the close of the year has been verified and further substantiated by certificate from the Bank.

"We have certified the Annual Statements as correctly showing the financial transactions of the Institute during the year, and the true position of it at the close thereof as shown by the Books and Records."

"Respectfully submitted,

(Signed) "P. S. ROSS & SONS,
Chartered Accountants."

Audited and Certified Correct.

P. S. ROSS & SONS,
Chartered Accountants.

Montreal, Jan. 5th, 1912.

APPOINTMENT OF SCRUTINEERS.

Messrs. James White, J. J. Penhale and J. M. Clark were appointed scrutineers of the ballots for the election of a President for the ensuing term. Subsequently, Mr. Clark declaring his inability to act, Mr. James McEvoy was appointed in his stead.

THE MINERAL PRODUCTION OF CANADA IN 1911.

Mr. J. McLeish then submitted a preliminary statement of the mineral production of Canada for the year 1911, as follows:

"The Preliminary Report on the Mineral Production of Canada just issued by the Mines Branch of the Department of Mines, shows a falling off in the mineral production in 1911 of about four and a half million dollars, the production for 1911 being reported as one hundred and two and a quarter million dollars as against one hundred and six and three-quarter million dollars during the previous year.

"The mining industry during the years 1909 and 1910 showed such substantial progress and large increase in output that it is not surprising a slight falling off should be shown in 1911, particularly when it is remembered that the long continued strike of coal miners in Alberta and the Crow's Nest District of British Columbia not only seriously reduced the coal output, but also, because of the closing down of the Granby smelter on account of the coke shortage, caused a lower production of copper, silver, and gold than would have otherwise been obtained.

"It is of course more a matter of coincidence than otherwise that the decrease in the value of coal production in 1911 should be practically identical with the total decrease in mineral production for the year.

"An examination of individual items shows that in point of value at least there has been a falling off in production in practically all of the metals, while with the exception of coal and petroleum there has been an almost general increase in the production of non-metallic products.

"The aggregate decreases total nearly eight million dollars, while increases of about 3½ million are shown, making the net falling off of 4½ million as already stated.

"The production of the more important metals and minerals is shown in the following tabulated statement in which the figures are given for the two years, 1910 and 1911, in comparative form, and the increase or decrease in value shown. Tabulated statements for both years, in greater detail, will be found on subsequent pages:

	1910.		1911.		Increase (+) or decrease (=) in value.
	Quantity.	Value.	Quantity.	Value.	
		$		$	$
Copper, lbs.	55,692,369	7,094,094	55,848,665	6,911,831	— 182,263
Gold, ozs.	493,707	10,205,835	.....	9,762,096	— 443,739
Pig iron, tons	800,797	11,245,622	917,535	12,306,860	+ 1,061,238
Lead, lbs.	32,987,508	1,216,249	23,525,050	818,672	— 397,577
Nickel, lbs.	37,271,033	11,181,310	34,098,744	10,229,623	— 951,687
Silver, ozs.	32,869,264	17,580,455	32,740,748	17,452,128	— 128,327
Other metallic products	.....	510,081	.....	409,674	— 100,407
Total	.....	59,033,646	.....	57,890,884	— 1,142,762
Less pig iron credited to imported ores	695,891	9,594,773	875,349	11,693,456	+ 2,098,683
Total metallic	.....	49,438,873	.....	46,197,428	— 3,241,445
Asbestos and asbestic, tons	102,215	2,573,603	126,914	2,943,107	+ 369,504
Coal, tons	12,909,152	30,909,779	11,291,553	26,378,477	— 4,531,302
Gypsum, tons	525,246	934,446	505,457	978,863	+ 44,417
Natural gas	.....	1,346,471	.....	1,820,923	+ 474,452
Petroleum, brls.	315,895	388,550	291,092	357,073	— 31,477
Salt, tons	84,092	409,624	91,582	443,004	+ 33,380
Cement, brls.	4,753,975	6,412,215	5,635,950	7,571,299	+ 1,159,084
Clay products	.....	7,629,956	.....	8,317,709	+ 687,753
Lime, bush.	5,848,146	1,137,079	7,227,310	1,493,119	+ 356,040
Stone	.....	3,650,019	.....	3,680,371	+ 30,352
Miscellaneous non-metallic	.....	1,993,008	.....	2,110,313	+ 117,305
Total non-metallic	.....	57,384,750	.....	56,094,258	— 1,290,492
Grand total	.....	106,823,623	.....	102,291,686	— 4,531,937

"The subdivision of the mineral production in 1910 and 1911 by provinces was approximately as follows:

Province.	1910.		1911.	
	Value of Production.	Per cent of Total.	Value of Production.	Per cent. of Total.
	$	%	$	%
Nova Scotia	14,195,730	13.29	15,354,928	15.01
New Brunswick	581,942	0.54	611,597	0.60
Quebec	8,270,136	7.74	9,087,698	8.88
Ontario	43,538,078	40.76	42,672,904	41.72
Manitoba	1,500,359	1.40	1,684,677	1.65
Saskatchewan	498,122	0.47	618,379	0.60
Alberta	8,996,210	8.42	6,404,110	6.26
British Columbia	24,478,572	22.92	21,237,801	20.76
North West Territories	4,764,474	4.46	4,619,592	4.52
Dominion	106,823,623	100.00	102,291,686	100.00

"Of the total production in 1911 a value of $46,197,428 or 45 per cent. is credited to metals and $56,094,258 to non-metallic products. Practically all of the metals with the exception of pig iron show a falling off in production in so far as value is concerned. In the case of copper, however, there was an increased output of the metal although the average price per pound was slightly lower than in 1910. The increase in pig iron production was quite considerable, although this is chiefly attributable to imported ore.

"Amongst the non-metallic products increases are shown in the production of arsenic, asbestos, feldspar, graphite, natural gas, pyrites, salt, and in nearly all of the structural materials, including cement, clay products, stone, lime, etc.

"Outside of the metallic products, the principal decreases are in coal and petroleum; the falling off in value of coal production alone being practically equivalent to the total net decrease for the year.

"There is comparatively little change in the relative importance of the provinces as mineral producers—Ontario contributed nearly 42 per cent. of the total in 1911; British Columbia nearly 21 per cent.; Nova Scotia 15 per cent.; Quebec

nearly 9 per cent., and Alberta 6 per cent. The order in 1910 was the same except that Alberta slightly exceeded Quebec in production.

"The provinces showing an increased output for the year are Nova Scotia, New Brunswick, Quebec, Manitoba, and Saskatchewan; those showing a falling off being Ontario, Alberta, and British Columbia.

"In Nova Scotia the coal industry was particularly active and to that and the clay and stone industries is the increase in in this province to be chiefly ascribed. There was a slight increase in New Brunswick. In Ontario the net result was a decrease of about $1,000,000 being chiefly in copper, nickel, and petroleum; on the other hand there were substantial increases in nearly all of the other products of which a great variety is obtained in this province. Manitoba produces gypsum, clay, and stone products; and Saskatchewan coal and clays.

"The difficulties incident to coal mining operations in Alberta and British Columbia have already been noted and these have been the chief cause of falling off in production in these provinces. In British Columbia notwithstanding the coke shortage and the consequent closing down of the Granby smelter for a portion of the year there was still a slight increase in the copper production although the output of silver, lead, and zinc was less than in 1910.

The following table shows the mineral production in detail. The figures are subject to revision:

Products.	Quantity.	Value.
METALLIC.		$
Copper, value at 12.376 cts. per pound, lbs.	55,848,665	6,911,831
Gold	.....	9,762,096
Pig iron from Canadian ore, tons	42,186	613,404
Iron ore sold for export, tons	39,162	86,812
Lead, value at 3.48 cents per pound, lbs.	23,525,050	818,672
Nickel, value at 30 cents per pound, lbs.	34,098,744	10,229,623
Silver, value at 53.304 cents per oz., ozs.	32,740,748	17,452,128
Cobalt and nickel oxides	.....	221,790
Zinc ore, tons	2,590	101,072
Total	.....	46,197,428

Products.	Quantity.	Value.
NON-METALLIC.		
Actinolite, tons	67	736
Arsenic, white, tons	2,097	76,237
Asbestos, tons	100,893	2,922,062
Asbestic, tons	26,021	21,045
Chromite, tons	27	351
Coal, tons	11,291,553	26,378,477
Corundum, tons	1,472	161,873
Feldspar, tons	17,718	51,924
Fluorspar, tons	34	238
Graphite, tons	1,269	69,576
Grindstones, tons	5,312	49,942
Gypsum, tons	505,457	978,863
Manganese, tons	5½	300
Magnesite, tons	991	5,531
Mica, tons	.....	119,863
Mineral pigments—		
Barytes, tons	50	400
Ochres, tons	3,622	28,333
Mineral water	.....	223,758
Natural gas	.....	1,820,923
Peat, tons	1,463	3,817
Petroleum, value at $1.22⅔ per barrel, brls.	291,092	357,073
Phosphate, tons	558	4,928
Pyrites, tons	82,666	365,820
Quartz, tons	60,526	83,865
Salt, tons	91,582	443,004
Talc, tons	7,300	22,100
Tripolite, tons	20	122
Total	.....	34,191,161
STRUCTURAL MATERIALS AND CLAY PRODUCTS.		$
Cement, Portland, brls.	5,635,950	7,571,299
Clay products—		
Brick, common, pressed, paving	.....	6,521,558
Sewerpipe	.....	799,756
Fireclay, drain tile, pottery, etc.	.....	996,395
Lime, bush.	7,277,310	1,493,119
Sand and gravel (exports), tons	573,494	408,110
Sand-lime brick	.....	424,241
Slate, sq.	1,833	8,248
Stone—		
Granite	.....	880,309
Limestone	.....	2,282,146
Marble	.....	140,903
Sandstone	.....	377,013
Total structural materials and clay products	.....	**21,903,097**
All other non-metallic	.....	**34,191,161**
Total value, metallic	.....	**46,197,428**
Total value, 1911	.....	**102,291,686**

Smelter Production.

General statistics of smelter production have been collected by this Branch since 1908. Complete returns have been received for the year 1911, except from one or two plants recently established for the treatment of Ontario silver-cobalt ores. It should also be explained that the accompanying statistics include the treatment of a small quantity of imported ores in the British Columbia smelters.

"The total quantity of ores treated in 1911 was 2,192,727 tons as compared with 2,683,714 tons treated in 1910.

"The ores treated may be conveniently classified as follows:

	1909.	1910.	1911.
	Tons.	Tons.	Tons.
Nickel-copper ores	462,336	628,947	610,834
Silver-cobalt - nickel - arsenic ores	8,384	9,466	8,504
Lead and other ores treated in lead furnaces	54,539	57,549	55,408
Copper-gold-silver ores	1,850,889	1,987,752	1,517 981
Total	2,376,148	2,683,714	2,192,727

"The closing of the Granby smelter due to coke shortage was the principal cause of the falling off in copper-gold ores treated.

"The products obtained in Canada from the treatment of these ores include: refined lead produced at Trail, B.C., and fine gold, fine silver, copper sulphate, and antimony produced from the residues of the lead refinery; silver bullion, white arsenic, nickel oxide, and cobalt oxide produced in Ontario from the Cobalt District ores. In addition to these refined products, blister copper, copper matte, and nickel copper matte are produced and exported for refining outside of Canada.

"The aggregate results of these smelting and refining operations for the years 1910 and 1911 are briefly summarized in the following table:

	1910.		1911.	
	Refined products.	Metals contained in matte, blister, and base bullion.	Refined products.	Metals contained in matte, blister, and base bullion.
Antimony, lbs.	.....	.....	30	.....
Gold, ozs.	13,298	197,181	15,270	175,189
Silver, ozs.	16,373,799	2,136,414	17,711,077	612,401
Lead, lbs.	32,987,508	.....	23,525,050	.....
Copper, lbs.	.....	56,149,299	.....	47,788,131
Copper sulphate, lbs.	163,228	.....	197,187	.....
Nickel, lbs.	.....	37,587,676	.....	34,098,744
Cobalt and nickel oxides, lbs.	13,508	.....	15,174	.....
Mixed oxides of cobalt and nickel, lbs.	108,178	.....	127,224	.....
White arsenic, lbs.	3,003,467	.....	4,194,209	.....

"Smelter products shipped outside of Canada for refining were: Blister copper, carrying gold and silver values 10,710 tons in 1911 as compared with 13,918 tons in 1910; copper matte carrying gold and silver values 11,320 tons in 1911 as against 11,519 tons in 1910; Bessemer nickel copper matte carrying small gold and silver values as well as metals of the platinum group 32,607 tons in 1911 as compared with 35,033 tons in 1910.

Gold.

"The gold production in 1911 is estimated as approximately $9,762,096, which, compared with the 1910 production of $10,205,835, shows a falling off of $443,739. The Yukon placer production in 1911 is estimated at $4,580,000 as against $4,550,000 in 1910, the total exports on which royalty was paid during the calendar year, according to the records of the Interior Department, being 277,430.97 ounces in 1911 and 275,472.51 ounces in 1910. The British Columbia production in 1911 was $4,989,524, of which the placer production, as estimated by the Provincial Mineralogist, was $468,000, smelter recoveries and bullion obtained from milling ores being valued at $4,521,524.

"The production in Nova Scotia is estimated at $142,000 all from milling ores. In Quebec there was a small recovery from

alluvial workings and a small content in the pyrite ores shipped, the total value of production being $12,443. Returns so far received from Ontario show a production of $37,929.

"The export of gold-bearing dust, nuggets, gold in ore, etc., in 1911 were valued at $7,493,523.

"Gold was imported during 1911 in bars, blocks, ingots, etc., to the value of $924,233.

Silver.

"The silver production of Canada, which has been very rapidly increasing during the past few years, will probably show but little change in 1911.

"Returns so far received appear to indicate a falling off of about 128,516 ounces. The total production of the year is estimated at 32,740,748 ounces valued at $17,452,128, of which 30,761,690 ounces were from Ontario, 1,910,323 ounces from British Columbia, 50,300 ounces from the Yukon, and 18,435 ounces from Quebec.

"The production in Ontario was slightly greater than that of the previous year and in British Columbia a falling off of nearly half a million ounces is shown.

"For British Columbia the figures represent the recovery as silver bullion or silver contained in smelter products, while for Ontario the figures represent the total silver content of ore and concentrates shipped less five per cent. allowed for smelter losses, together with bullion shipments.

"The total shipments of ore and concentrates from the Cobalt District and adjacent mines were about 16,234 tons, containing approximately 28,817,198 ounces, in addition to which 3,334,052 ounces were shipped as bullion. The average silver content of ore and concentrates shipped was thus about 1,744 ounces or $929.62 per ton as compared with an average of 867 ounces in 1910 and 840 ounces in 1909. The 1911 shipments were chiefly high grade ore averaging over 3,400 ounces and concentrates averaging over 850 ounces.

"The shipments in 1910 were 28,684 tons of ore containing 23,797,111 ounces of silver or an average of 830 ounces per ton; 6,943 tons of concentrates containing 7,111,579 ounces or an

average of 1,024 ounces per ton and bullion containing 1,003,111 fine ounces.

"The exports of silver in ore, etc., as reported by the Customs Department were 31,216,725 ounces, valued at $15,807,366. There was also an importation of silver in bars, blocks, sheets, etc., valued at $847,645.

"The price of refined silver in New York varied between a minimum of 51⅝ cents per ounce in February, and a maximum of 56⅜ cents in November, the average monthly price being 53.304 as compared with an average monthly price of 53.486 in 1910.

Copper.

"There is practically no production of refined copper in Canada, and the production is represented by the copper contents of smelter products, matte and blister copper produced, together with the amount of copper contained in ores exported estimated as recoverable.

"The total production on this basis in 1911 was 55,848,665 pounds, valued at $6,911,831 as compared with 55,692,369 pounds valued at $7,094,094 in 1910, an increase in quantity of 156,296 pounds, but a falling off in total value owing to the slightly lower price of copper in 1911.

"The total copper contents of ores shipped in 1911 was approximately 67,282,590 pounds, being 3,123,189 pounds from Quebec, 21,402,221 pounds from Ontario and 42,757,180 pounds from British Columbia. This record is of special interest as illustrating the distinction between ore contents and smelter recoveries.

"Of the production or smelter recovery in 1911, Quebec province is credited with 2,436,190 pounds as against 877,347 pounds in 1910. This is altogether from pyrite ores, which are mined primarily for their sulphur contents. Ontario's production in 1911 was 17,932,263 pounds as compared with 19,259,016 pounds in 1910, all being from the nickel-copper ores of the Sudbury district.

"The production in British Columbia, notwithstanding the failure of the domestic coke supply due to strikes in the coal mines of the Crow's Nest Pass district and the consequent clos-

ing of the Granby smelter for nearly five months, shows a slight increase, being estimated at 35,480,212 pounds in 1911 as against 35,270,006 pounds in 1910.

"The British Columbia Copper Co. made a larger output, using imported coke; and production from Coast mines, particularly the Britannia and Marble Bay, was specially heavy. The increased production from these mines more than balanced the falling off at Granby.

"The New York price of electrolytic copper varied during the year between the limits of 11.85 cents and 14.05 cents per pound, the average being 12.376. During December the price ranged from 13 to 14 cents. The average monthly price in 1910 was 12.738 cents.

"The total exports of copper contained in ore, matte and blister, etc., according to Customs Department returns were 55,287,710 pounds, valued at $5,467,725, which agrees fairly closely with the record of production.

"The total imports of copper in 1911 were valued at $4,936,459 and included crude and manufactured copper to the extent of 35,155,550 pounds valued at $4,632,452; copper sulphate 2,191,899 pounds, valued at $88,419, and other copper manufactures valued at $215,588.

Lead.

"The total production of pig and manufactured lead in 1911 was 23,525,050 pounds, valued at $818,672 or an average of 3.48 cents per pound, the average wholesale or producer's price of pig lead in Montreal for the year. There was also a small production of lead concentrate from Calumet Island, Que., the shipments being about 45 tons.

"The production of lead in 1910 was 39,987,508 pounds, thus showing a considerable falling off in 1911. The decrease is probably chiefly due to the diminished tonnage from the St. Eugene mine in East Kootenay and the idleness of some of the more important mines of the Slocan following the destruction of the Kaslo and Slocan Ry. by forest fires in 1910. The Bear Lake branch of the C. P. R. now under construction will provide shipment facilities for these properties.

"The Sandon and Silverton camps would seem to promise an increased tonnage of silver-lead ores in the near future.

"The exports of lead in ore in 1911 are reported as 32 tons and of pig lead only 36 tons, as compared with exports of 23 tons and 3,856 tons respectively in 1910.

"The total value of the imports of lead and lead products in 1911 was $1,049,276 including 13,135 tons in the form of pig lead, bars, sheets, tea lead, etc., valued at $706,020; manufactures of lead, valued at $108,012; litharge and lead pigments having an equivalent lead content of approximately 2,395 tons, valued at $235,244.

"The total value of the imports of lead and lead products in 1910 was $833,743 and with the exception of manufactures, valued at $107,688, represented an equivalent lead content of 10,544 tons.

"The average monthly price of lead in Montreal during 1911 was 3.48 cents per pound and in Toronto 3.53 cents. These are producer's prices for lead in car lots as per quotations kindly furnished by Messrs. Thos. Robertson & Co. The average monthly price of lead in New York during the year was 4.42 cents, and in London £13.970 per long ton equivalent to 3.035 cents per pound.

"The amount of bounty paid during the twelve months ending December 31, 1911, on account of lead production was $219,-557.70 as compared with payments of $318,308.28 in 1910.

Nickel.

"The mining and smelting of nickel-copper ores in the Sudbury District of Ontario was carried on actively throughout the year and although the production was slightly less than in 1910 it was still very much larger than in any previous year. Active operations were as usual carried on by the Mond Nickel Company at Victoria Mines and the Canadian Copper Co. at Copper Cliff, Creighton, Crean Hill, etc., while the Dominion Nickel Company continued to develop their property at Norman Station.

"The ore is first roasted and then smelted and converted to a Bessemer matte containing from 77 to 82 per cent. of the com-

bined metals, copper and nickel, the matte being shipped to the United States and Great Britain for refining. A portion of the matte is now used for the production of the alloy, monel metal, which is obtained directly from the matte without the intermediate refining of either nickel or copper.

"The total production of matte in 1911 was 32,607 tons, valued at the smelters at $4,945,593, a decrease of 2,426 tons or 6.9 per cent. from the production of 1910. The metallic contents were copper 17,932,263 pounds, and nickel, 34,098,744 pounds.

"The aggregate results of the operations on the Sudbury District nickel-copper ores during the past four years were as follows in tons of 2,000 pounds:—

	1908.	1909.	1910.	1911.
Ore mined	409,551	451,892	652,392	612,511
Ore smelted	360,180	462,336	628,947	610,834
Bessemer matte produced	21,197	25,845	35,033	32,607
Copper contents of matte	7,503	7,873	9,630	8,966
Nickel contents of matte	9,572	13,141	18,625	17,049
Spot value of matte shipped	$2,930,989	$3,913,017	$5,380,064	$4,945,592
	Pounds.	Pounds.	Pounds.	Pounds.
Exports to Great Britain	2,554,486	3,843,763	5,335,331	5,023,393
Nickel contents of matte	16,865,407	21,772,635	30,679,451	27,596,578
	19,419,893	25,616,398	36,014,782	32,619,971

"The price of refined nickel in New York remained practically constant throughout the year—quotations in the '*Engineering and Mining Journal*' being large lots, contract business, 40 to 45 cents per pound during the first four months, and 40 to 50 cents from May to December. Retail spot from 50 cents for 500 pound lots up to 55 cents for 200 pound lots. The price for electrolytic is 5 cents higher.

"The imports of nickel anodes in 1911 were valued at $34,199 as compared with $23,317 in 1910.

Iron.

"Iron Ore.—The total shipments of iron ore in 1911 are reported as 210,344 tons, valued at $522,319. These may be classified as magnetite 72,945 tons, and hematite 137,399 tons.

"In 1910 the total shipments were 259,418 tons comprising magnetite 127,768 tons; hematite 130,380 tons, and bog ore 1,270 tons.

"Exports of iron ore from Canada during 1911 are recorded by the Customs Department as 37,686 tons, valued at $133,411 The exports were chiefly from Bathurst, New Brunswick.

"The shipments from the Wabana mines, Newfoundland, in 1911 by the two Canadian companies operating there were 1,181,463 short tons of which 765,184 tons were shipped to Sydney and 416,279 tons to the United States and Europe.

"Pig Iron.—The total production of pig iron in Canadian blast furnaces in 1911 was 917,535 tons of 2,000 pounds, valued at approximately $12,306,860 as compared with 800,797 tons, valued at $11,245,622 in 1910.

"Of the total output in 1911, 20,758 tons were made with charcoal as fuel and 896,777 tons with coke. The classification of the production according to the purpose for which it was intended was as follows:—

"Bessemer 208,626 tons; basic 464,220 tons; foundry and miscellaneous 244,686 tons.

"The amount of Canadian ore used during 1911 was 67,434 tons; imported ore 1,628,368 tons; mill cinder etc., 30,298 tons.

"The amount of coke used during the year was 1,121,321 tons comprising 543,933 tons from Canadian coal and 577,388 tons imported coke or coke made from imported coal. There were also used 1,190,459 bushels of charcoal.

"Limestone flux was used to the extent of 625,216 tons.

"In conection with blast furnace operations there were employed 1,778 men and $1,097,355 were paid in wages.

"The total daily capacity of 18 completed furnaces was according to returns received 3,630 tons and the number of furnaces in blast December 31, 1911, was 12.

Pig Iron and Steel.

"The production of pig iron by provinces in 1910 and 1911 was as follows:

Provinces.	1910.			1911.		
	Tons.	Value.	Value per Ton.	Tons.	Value.	Value per Ton.
		$	$		$	$
Nova Scotia	350,287	4,203,444	12 00	390,242	4,682,904	12 00
Quebec . . .	3,237	85,255	26 34	658	17,282	26 34
Ontario . . .	447,273	6,956,923	15 55	526,635	7,606,674	14 44
Total . . .	800,797	11,245,622	14 04	917,535	12,306,860	13 41

"The exports of pig iron during the year are reported as 5,870 tons, valued at $271,968 an average of $46.33 per ton. Probably the greater part of this is ferro-silicon and ferro-phosphorus, produced at Welland and Buckingham, respectively.

"There were imported during the year 208,487 tons of pig iron, valued at $2,610,989 and 17,226 tons of ferro-manganese, etc., valued at $429,465.

"Steel.—The production of steel ingots and castings in 1910 is reported as 876,215 tons of 2,000 pounds of which 861,493 tons were ingots and 14,772 tons castings.

"The production in 1910 was 822,284 tons, including 803,600 tons of ingots and 18,684 tons of castings.

"The production of open hearth and Bessemer steel has been for four years as follows:—

	1908.	1909.	1910.	1911.
	Tons.	Tons.	Tons.	Tons.
Ingots—Open-hearth (basic)	443,442	535,988	580,932	651,676
Bessemer (acid)	135,557	203,715	222,668	209,817
Castings-Open-hearth	9,051	14,013	18,085	13,982
Other steels	713	1,003	599	740
Total	588,763	754,719	822,284	876,215

Asbestos.

"For a number of years past the annual output of asbestos has exceeded the sales. In 1911, however, the sales have been greatly increased, but at considerably reduced prices. Returns received for the year 1911 show a total output of 96,299 tons as compared with 100,430 tons in 1910. The sales in 1911 are, however, reported as 100,893 tons, valued at $2,922,062, or of $28.96 per ton, as compared with 77,508 tons valued at $2,555,-974, or an average of $32.98 per ton in 1910, an increase of 23,385 tons or 30 per cent. in quantity but only $366,088, or 14 per cent. in total value. Stocks on hand at December 31, 1911 are reported as 34,568 tons, valued at $1,509,100 as compared with 41,903 tons, valued at $1,943,171 on December 31, 1910.

"The average number of men employed in mines and mills during 1911, was 2,707 at a wage cost of $1,231,896.

"The total quantity of asbestos rock sent to mills is reported as 1,484,691 tons, which with a mill production of 91,237 tons shows an average estimated recovery of about 6.14 per cent.

"The following tabulated statement shows the output and sales during 1911 and the stock on hand at the end of the year—

	Output.	Sales.			Stock on hand Dec. 31.	
	Tons.	Tons.	Value.	Per Ton.	Tons.	Value.
			$	$	$	$
Crude No. 1.....	1,467.9	1,301.4	342,855	263 45	1,256	327,508
Crude No. 2.....	3,594.5	3,562.7	402,107	112 86	3,222.7	404,198
Mill stock No. 1..	20,376	18,315	916,678	50 05	8,471	380,570
Mill stock No. 2..	39,289	47,326	991,370	20 95	17,794	365,457
Mill stock No. 3..	31,572	30,388	269,052	8 85	3,824	31,367
Total asbestos .	96,299.4	100,893 1	2,922,062	28 96	34,567.7	1,509,100
Asbestic	.....	26,021	21,045	81	.....	.....

"In the absence of a uniform classification of asbestos of different grades the above subdivisions have been adopted purely on a valuation basis; crude No. 1 comprising material valued at

$200 and upwards, and crude No. 2 under $200; mill stock No. 1 includes stock valued at from $30 to $100; No. 2 from $15 to $30; No. 3 under $15.

"Output, sales and stocks in 1910 were as follows:—

	Output.	Sales.			Stock on hand Dec. 31.	
	Tons.	Tons.	Value.	Per Ton.	Tons.	Value.
			$	$		$
Crude No. 1.....	2,181	1,817	471,675	259 58	1,702	446,675
Crude No. 2	3,268	1,923	192,833	100 28	3,219	440,571
Mill stock No. 1..	16,720	13,480	735,244	54 54	6,978	398,895
Mill stock No. 2..	56,395	43,414	1,013,251	23 34	26,613	628,528
Mill stock No. 3..	21,866	16,874	142,971	8 47	3,391	27,177
Total asbestos..	100,430	77,508	2,555,974	32 98	41,903	1,943,846
Asbestic	.....	24,707	17,629	0 71	.....	.....

"Exports of asbestos during the twelve months ending December 31, 1911, are reported by the Customs Department as 75,120 tons, valued at $2,067,259, comprising 62,551 tons, valued at $1,732,541 to the United States; 7,511 tons valued at $192,993 to Great Britain; 1,841 tons, valued at $62,737 to Belgium; 2,596 tons, valued at $52,047 to France, 361 tons, valued at $20,494 to Germany, and 260 tons, valued at $6,447 to other countries.

"The imports of manufactures of asbestos during the same period are reported as valued at $319,815.

Coal and Coke.

"The long continued strike which took place in the coal mines of Southern Alberta and Eastern British Columbia, was responsible for a considerable falling off in the coal production of Canada in 1911.

"The total coal production during the past year, comprising sales and shipments, colliery consumption, and coal used in making coke is estimated at 11,291,553 tons of 2,000 lbs. valued at $26,378,477. This is a decrease of 1,617,599 tons or nearly

12.53 per cent. from the production in 1910, which was 12,909,-152 tons valued at $30,909,779.

"There was an increase of 562,978 tons in the Nova Scotia production, that of New Brunswick remained practically stationary while an increase of about 23,097 tons is shown in Saskatchewan.

"In Alberta, the decrease was about 1,396,412 tons or 48 per cent. and British Columbia also shows a falling off of 794,-243 tons or nearly 24 per cent.

"The production by provinces was approximately as follows the figures for 1909 and 1910 being also given:—

Province.	1909.		1910.		1911.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.
		$		$		$
Nova Scotia	5,652,089	1,354,643	6,431,142	12,919,705	6,994,120	14,050,687
British Columbia..	2,606,127	8,144,147	3,330,745	10,408,580	2,536,502	7,926,569
Alberta	1,994,741	4,838,109	2,894,469	7,065,736	1,498,057	3,933,958
Saskatchewan	192,125	296,339	181,156	293,923	204,253	342,921
New Brunswick ..	49,029	98,496	55,455	110,910	55,781	111,562
Yukon Territory..	7,364	49,502	16,185	110,925	2,840	12,780
Totals	10,501,475	24,781,236	12,909,152	30,909,779	11,291,553	26,378,477

"The exports of coal in 1911 were 1,500,639 tons, valued at $4,357,074 as compared with exports of 2,377,049 tons in 1910, valued at $6,077,350, a decrease in exports of 876,410 tons.

"Imports of coal during the year include bituminous 8,905,815 tons valued at $18,407,603; slack 1,632,500 tons, valued at $2,090,796 and anthracite 4,020,577, valued at $18,794,192, or a total of 14,558,892 tons valued at $39,292,591.

"The imports of coal in 1910 were, bituminous 5,966,466 tons; slack 1,365,281 tons and anthracite 3,266,235 tons, or a total of 9,872,924.

"Coke.—The total production of oven coke in 1911 was 847,402 tons valued at $2,340,674 as compared with the production of 902,715 tons valued at $3,462,872 in 1910. The total quantity of coal charged to ovens was 1,228,700 short tons.

"By provinces the production was, Nova Scotia, 469,305 tons; Ontario, 259,554 tons (made from imported coal); Alberta, 36,216 tons, and British Columbia, 82,327 tons. All the coke produced was used in Canada with the exception of 9,290 tons sold for export to the United States.

"The quantity of coke imported during the calendar year was 751,389 tons, valued at $1,843,248 as compared with imports of 737,088 tons, valued at $1,908,725 in 1910.

Petroleum and Natural Gas.

"A further falling off is shown in the output of petroleum, the production in 1911 being 291,092 barrels, or 10,188,219 gallons, valued at $357,073 as compared with 315,895 barrels or 11,056,337 gallons, valued at $388,550 in 1910. The average price per barrel at Petrolea in 1911 was $1.22 2-3, and in 1910, $1.23.

"These statistics of production have been furnished by the Trade and Commerce Department and represent the quantities of oil on which bounty was paid, the total payments being $152,823.29 in 1911 and $165,845.06 in 1910.

"The production in Ontario by districts as furnished by the Supervisor of Petroleum Bounties was in 1911 as follows in barrels:—Lambton, 184,450; Tilbury and Romney, 48,708; Bothwell, 35,244; Dutton, 6,732; and Onondaga, 13,501. In 1910 the production by districts was Lambton 205,456; Tilbury and Romney, 63,058; Bothwell, 36,998; Leamington 141; Dutton 7,752, and Onondaga, 1,005.

"The production in New Brunswick in 1911 was 2,461 barrels as against 1,485 barrels in 1910.

"Exports of refined oil in 1911 were 489 gallons, valued at $73. There was also an export of naphtha and gasoline of 23,959 gallons, valued at $4,427.

"The imports of petroleum and petroleum products again show a very large increase. The total imports of petroleum oils, crude and refined, in 1911 was 116,892,689 gallons, valued at $6,009,730, in addition to 1,959,787 pounds of wax and candles, valued at $106,424. The oil imports included crude oil 71,637,533 gallons, valued at $2,187,952; refined and illuminating oils 13,-

690,962 gallons, valued at $722,403; gasoline 23,338,773 gallons, valued at $1,976,032; lubricating oils 5,308,917 gallons, valued at $806,452; and other petroleum products 2,916,504 gallons, valued at $316,891.

"The total imports in 1910 were 84,629,334 gallons of petroleum oils, crude and refined, valued at $4,826,763 and 1,362,235 pounds of wax and candles, valued at $80,106.

"A large increase is shown in the production of natural gas in 1911, the total value being reported as $1,820,923 of which $96,665 was the production in Alberta and $1,724,258 in Ontario. These values represent as closely as can be ascertained the value received by the owners of the wells for gas produced and sold or used and do not necessarily represent what the consumers have to pay for the gas since in many cases the gas is resold once or twice by pipe line companies before reaching the consumer.

"The total quantity of gas used in Ontario was about 9,869 million feet and in Alberta probably over 611 million feet.

The production of natural gas in 1910 was valued at $1,346,471 and represented about 7,952 million feet.

Cement.

"Complete statistics have been received from the manufacturers of cement covering their production and shipments during the year 1911. These returns show that the total quantity of cement made during the year, including both Portland and slag cement, was 5,677,539 barrels as compared with 4,396,282 barrels in 1910, an increase of 1,281,257 barrels, or 29 per cent.

"The total quantity of Canadian Portland cement sold during the year was 5,635,950 barrels as compared with 4,753,975 barrels in 1910, an increase of 881,975 barrels, or 18.5 per cent.

"The total consumption of Portland cement in 1911 including Canadian and imported cement and neglecting an export of Canadian cement, valued at $4,067, was 6,297,866 barrels as compared with 5,103,285 barrels in 1910, or an increase of 1,194,581 barrels, or 23.4 per cent.

"Detailed statistics of production during the past four years are shown as follows:—

	1908.	1909.	1910.	1911.
	Barrels.	Barrels.	Barrels.	Barrels.
Portland cement sold	2,665,289	4,067,709	4,753,975	5,635,950
" " manufactured	3,495,961	4,146,708	4,396,282	5,677,539
Stock on hand January 1..	383,349	1,098,239	1,189,731	844,741
Stock on hand December 31	1,214,021	1,177,238	832,038	903,590
Value of cement sold	$3,709,063	$5,345,802	$6,412,215	$7,571,299
Wages paid	$1,275,638	$1,266,128	$1,409,715	$2,103,838
Men employed	3,029	2,498	2,220	3,010

"The average price per barrel at the works in both 1910 and 1911 was $1.34, as compared with an average price of $1.31 in 1909 and $1.39 in 1908.

"The imports of Portland cement during the twelve months ending December 31, 1911, were 2,316,707 cwt., valued at $834,879. This is equivalent to 661,916 barrels of 350 pounds at an average price per barrel of $1.26. The imports in 1910 were 349,310 barrels, valued at $468,046 or an average price per barrel of $1.34.

"The imports from Great Britain during 1910 were 190,506 barrels, valued at $210,839; from the United States 441,317 barrels, valued at $575,768; from Belgium 2,683 barrels, valued at $2,019; from Hong Kong 22,059 barrels, valued at $38,292; and from other countries 5,351 barrels, valued at $7,962.

"Following is an estimate of the Canadian consumption of Portland cement for the past five years:—

Calendar Years.	Canadian.		Imported.		Total
	Barrels.	Per cent.	Barrels.	Per cent.	Barrels.
1907	2,436,093	78	672,630	22	3,108,723
1908	2,665,289	85	469,049	15	3,134,338
1909	4,067,709	97	142,194	3	4,209,903
1910	4,753,975	93	349,310	7	5,103,285
1911	5,635,950	89.5	661,916	10.5	6,297,866

THE PROVINCE OF ONTARIO IN 1911.

Mr. Thomas W. Gibson, Deputy Minister of Mines for Ontario, in presenting the statistics of mineral production of that

Province for the year 1911, remarked that Ontario now occupied the premier position among the mineral producing provinces of the Dominion. He said:

"It is gratifying to be able to state that the production of the Province represented a value, on the basis of computation adopted by the Bureau of Mines, of $41,432,898 as compared with the 1910 valuation of $39,313,895; or an increase of $2,119,003. Considering the returns in detail, it will be noted that the production of silver shows an increase of about one million ounces, the output in 1911 having been 31,507,791 ounces as against a production of 30,558,825 ounces in 1910. There was a decline, though not to a serious degree, in the nickel-copper production. At the close of 1911 the industry was extremely active, and the outlook for the present year is promising. The production of gold in Ontario has not been considerable, heretofore, but the future in respect of an increased annual gold yield appears auspicious, more especially as a result of the development of the gold mines of the Porcupine area, which, it is hoped, will become importantly productive. Referring to the statistics of non-metallic products, it may be observed that the production of crude petroleum, which for a number of years past has been declining, again shows diminution. The main field of production is in the vicinity of Petrolea and Oil Springs, in the County of Lambton. There the output of oil per well is extremely low, and only in consequence of the large number of wells still in operation is the aggregate maintained. Unless some reservoirs of petroleum are found in Ontario, there is reason to fear that the industry will continue to decline. It is meanwhile, possible that a new field may be developed at Milton, where quite recently a new strike of oil was made. It is satisfactory to note, however, that the output of natural gas continues to increase, the production in 1911 representing a value of approximately $2,000,000, constituting a record yield.

"In conclusion I may remark that during the past year two metals were added to the list of those known to occur in Ontario. Thus Mr. A. G. Burrows, of the Bureau of Mines, recognized the discovery of tungsten, in the form of scheelite, at the Jupiter Mine, Porcupine; and mercury has been found in as-

sociation with some of the cobalt minerals at the Nipissing Mine, Cobalt.

"A preliminary statement, showing the production of the mines and metalliferous works of the Province is contained in the following table:—

Metallic	Quantity	Value.
		$
Gold, oz.	2,153	42,638
Silver, oz.	31,507,791	15,949,019
Cobalt in crude cobalt material, lbs.	234,749	58,687
Cobalt oxide, cobalt-nickel oxide, etc., lbs.	111,823	112,203 3,664,474
Nickel, tons	17,049	1,281,118
Copper, tons	8,966	445,930
Iron ore, tons	175,631	7,716,314
Pig iron, tons	526,610	
		29,270,383
Less Ontario iron ore (67,631 tons) smelted into pig iron		172,391
		29,097,992
Non-Metallic		
Arsenic, lbs.	4,341,078	74,609
Brick Common, No.	316,000,092	2,480,177
Tile, drain, No.	21,461,000	343,956
Brick, pressed, etc., No.	51,843,548	562,345
Brick, paving, No.	4,522,400	86,658
Building and crushed stone	.....	882,667
Calcium carbide, tons	1,383	84,437
Cement, Portland, bbls.	2,943,003	3,563,995
Corundum, tons	1,471	147,158
Feldspar, tons	17,697	51,610
Fluorspar, tons	30	200
Graphite, tons	894	36,492
Gypsum, tons	20,335	32,535
Iron pyrites, tons	43,629	118,457
Lime, bush.	2,335,085	394,551
Mica, tons	322	43,058
Natural gas	.....	2,068,429
Peat, tons	1,180	2,830
Petroleum, Imp. gals.	10,102,081	353,573
Phosphate, tons	20	240
Pottery	.....	50,500
Quartz, tons	56,723	64,405
Salt, tons	88,689	430,835
Sewer pipe	.....	410,064
Talc, tons	7,104	51,125
Total non-metallic production		12,334,906
Add net metallic production		29,097,992
Total production		41,432,898

Mining Accidents in 1911.

Mr. E. T. Corkill, Chief Inspector of Mines, presented a report dealing with mining accidents in the Province during 1911. From this report the following excerpt is taken:—

"During the year 1911 in and about the mines regulated by the Mining Act of Ontario there were thirty-three fatal accidents representing a loss of life of thirty-six. The fatalities below ground numbered 33 and above ground 3. Altogether, at the mines, metallurgical works and quarries regulated by the Mining Act there were 45 fatal accidents, the number of fatilities being 49, an increase of 1 over the number killed in 1910. The accidents at metallurgical works and quarries are separated in this report from the accidents at the mines, and are set out in tables following those for the mine accidents. In former reports of the Bureau of Mines all the accidents have been included in the one table, and this should be taken into consideration in comparing the accidents for 1911 with those of previous years.

"The total number of serious accidents in the mines of Ontario reported to the Bureau of Mines was 111, resulting in 36 men killed and 86 injured. Of these accidents 82 occurred below ground and 29 above ground. The fatal accidents took place in mines operated by 21 different companies.

"At the metallurgical works there were 33 accidents which caused the death of 9 and serious injuries to 25 men.

"The number of accidents therefore at mines and works regulated by the Mining Act of Ontario is 144, causing the death of 49 men and serious injuries to 111 men. Of the seriously injured, 60 received their injuries below ground and 51 above ground.

"A 'serious' accident is not defined by statute, but is here taken to mean an accident by which a man is incapacitated for work for more than seven days.

"Investigation and report were made in 30 out of the 33 fatal accidents in the mines, in 6 out of 9 fatal accidents at the metallurgical works, and in all the quarry accidents. In accordance with the requirements of the Mining Act, inquests were held on most of the men killed; and to assist in bringing out the

facts, were attended by either the Inspector or the writer. In a few instances, through lack of knowledge on the part of the Coroner as to the law requiring an inquest, none was held. An investigation in such cases was made by the Inspector or the writer, and the evidence of witnesses taken under oath.

Analysis of Fatalities.

"By months the 36 fatalities occurred as follows: January, 6; February, 1; March, 6; April, 0; May, 3; June, 4; July, 0; August, 0; September, 3; October, 2; November, 4; December, 7; total—36.

"A comparison of the causes of the fatalities at the mines for 1910 and 1911 is as follows:—

	1910. Per cent.	1911. Per cent.
Falls of ground	19.0	5.5
Shaft accidents	21.6	22.2
Explosives	27.0	44.5
Miscellaneous (underground)	8.1	19.5
Surface	24.3	8.3

"These figures show a marked decrease in the accidents from falls of ground and in surface accidents, but a large increase in those caused by explosives.

"There were employed at the producing and non-producing mines during 1911 approximately 9,423 men. At these mines 36 men were killed, which is equivalent to 3.82 per 1,000 men employed."

THE PROVINCE OF QUEBEC IN 1911.

In presenting a preliminary statement of the mineral production of the Province of Quebec for the year 1911, Mr. T. C. Denis, Superintendent of Mines, pointed out that the yield represented the highest recorded to date, the valuation being nearly one and a quarter million dollars in excess of that for 1910. Mr. Denis said:—

"Despite the unfavourable conditions under which the asbestos industry laboured during 1911, the shipments of this

substance from the mines show a substantial increase in both tonnage and value, although the average returns per ton is somewhat less than in 1910.

"In copper and sulphur ore, we note that the McDonald mine at Weedon is now shipping steadily and contributed a large proportion of the production.

"There has been a resumption of gold production from the alluvial deposits of the Beauce region, and this marks a turning point in our gold industry.

"Graphite and mica have also been produced in greater quantities than last year. The graphite production is the highest yet recorded.

"On the other hand, we have to deplore a decrease in the production of iron ores. The bog iron ores of the St. Maurice district, and of Drummond County, seem to be passing away and no new deposits have yet been brought into prominence to replace them.

"In 1900 the mineral production of the Province of Quebec was a little over two and a half million dollars; in 1911, this total exceeded eight and a half millions, which augurs well for the future of our mineral industry.

Mineral Production of Quebec, 1911.

Product.	1911		Value 1910
	Quantity	Value	
Asbestos, tons	99,352	$2,939,006	$2,667,829
Asbestic, tons	25,732	19,802	17,612
Copper and Sulphur Ore, tons..	38,554	240,097	145,165
Gold, ounces	590	11,800	
Silver, ounces	23,000	11,500	
Bog Iron Ore, tons	931	4,041	4,406
Ochres, tons	3,612	28,174	33,185
Chromite	197	2,469	3,734
Mica	.....	76,433	51,901
Phosphate, tons	558	5,595	3,182
Graphite, lbs.	753,405	33,588	15,896
Mineral Waters, gallons	117,462	62,607	68,155

Product—*Continued.*	1911		Value 1910
	Quantity	Value	
Titaniferous Ores, tons	3,789	5,684	5,292
Slate	.....	8,248	18,492
Cement, bbls.	588,283	1,931,183	1,954,646
Magnesite, tons	885	6,416	2,160
Marble	.....	143,457	151,103
Flagstone	.....	500	890
Granite	.....	308,545	291,240
Lime, bush.	.....	284,334	279,306
Limestone	.....	1,081,059	503,173
Bricks, M.	130,297	1,135,501	906,375
Tiles, Drain and Sewer Pipe, Pottery, etc.	.....	100,000	197,526
Quartz, tons	500	1,125	2,013
Feldspar, tons	30	600	
Peat, tons	175	700	
Glass Sand	.....	1,179	
Sand	.....	114,500	
Totals	.....	$8,567,143	$7,323,281

MINING IN THE MARITIME PROVINCES, 1911.

The Secretary presented reviews of the mineral industries of the Maritime Provinces in 1911, kindly prepared for the occasion by Mr. Hiram Donkin, Deputy Commissioner of Mines of Nova Scotia, and the Hon. W. C. H. Grimmer, Surveyor-General of New Brunswick, respectively. These reports follow:

NOVA SCOTIA.

The conditions obtaining in the mineral industry of the Province during 1911 were eminently satisfactory. This is evidenced by the increased production, constituting a record achievement, and to which aggregate nearly every branch of the industry contributed. A further satisfactory feature was the absence of labour troubles; while the protracted and disastrous strike at the Springhill collieries was settled, and towards the close of the year the production of coal from this district was resumed.

The mineral output in detail is shown in the following table:—

Minerals.	QUANTITY.
Coal raised (gross tons)	6,208,444
*Iron ore (net tons)	53,595
Pig iron made (net tons)	397,615
Steel ingots made (net tons)	438,922
Limestone quarried (net tons)	525,286
Coke made (net tons)	545,619
Gypsum quarried (gross tons)	297,641
Building stone quarried (net tons)	11,226
Bricks made	23,273,700
Drain pipe and tile made (feet)	1,431,761
Grindstone quarried (net tons)	380
Gold-bearing ore mined (net tons)	18,320
Gold produced (ounces)	8,389
Manganese ore (net tons)	150
Antimony concentrate (net tons)	191
Moulding sand (net tons)	380
Tungsten ore (net tons)	75
Sulphate of Ammonia	3,971

*Iron ore imported during the year, 853,904 net tons.

Coal.—The output of 6,208,444 tons is the second largest output in the history of coal mining in the Province, and was only surpassed by the output of 1908, when 6,299,282 tons were mined, a difference of 90,838 tons. While the sales, amounting to 5,556,464 tons, exceeded those of 1908 (the former record) by 70,971 tons.

The distribution of the coal sold during the year was:—

Market.	TONS.
Nova Scotia	2,108,665
New Brunswick	541,591
Newfoundland	184,195
Prince Edward Island	80,637
Quebec	2,067,831
United States	332,301

Market.	TONS.
St. Pierre	9,024
Other countries	1,992
Bunker	204,681
Time Charter Boats	25,545

During the year thirty-six collieries were actively productive; while, in addition, at six collieries development work was in progress preparatory to producing coal. Most of these properties will commence production during the present year.

There were employed in and about the mines, underground, surface and on construction, a total of 12,522 persons and 992 horses.

The total number of accidents during the year at all the collieries was 139, of these 36 were fatal, and 103 minor accidents. This being one fatal accident for every 172,450 tons of coal mined and one fatal accident for every 348 men employed, the accident rate per thousand of men employed was 2.9. The causes of accident were:—

Killed by fall of coal or rock	12	or 33.3%
Killed by boxes or cages	12	or 33.3%
Killed by explosion of gas	8	or 22.2%
Drowned in mine	2	or 5.5%
Killed by fall of timber	1	or 2.8%
Killed by falling down shaft	1	or 2.8%
Total	36	99.9%

At the present time the industry is active, and indications are that the production of 1912 will exceed the production of 1911 by several hundred thousand tons.

Gold.—Gold mining was prosecuted in 19 different districts and resulted in the production of 8,389 ounces of bullion, from 18,320 tons of gold-bearing rocks mined and crushed. In 1910 two of the largest mines in the Province, namely, the Richardson mine at Goldboro and the Oldham-Sterling mine at Oldham, were closed, to which may be attributed the decrease of gold production in 1911.

Iron.—Iron ore was mined at Torbrook by the Canada Iron Corporation. This company has erected a concentrating plant

at Nictaux, about three miles distant from the mine. Mining operations were discontinued in August, but will be resumed directly market conditions improve.

Gypsum.—The gypsum quarries throughout the Province were in steady operation during the year. The production was approximately that of 1910. A number of new quarries are being opened, however, and an increased output may be expected for the future.

Limestone.—The quantity of limestone quarried for fluxing purposes is the largest in the history of the industry.

Building Stone.—The output of the building stones from the different quarries shows a small increase when compared with the output of 1910.

Tungsten.—At Moose River the Scheelite Mines, Limited, a company organized during the year, acquired the Tungsten property of the Nova Scotia Tungsten Company, continuing development operations with very satisfactory results. A concentrating mill is being erected and will, it is hoped, be in operation at an early date.

Manganese.—At New Ross, the development of a vein of high-grade manganese ore was undertaken last year. A shaft was sunk to a depth of 130 feet, and drives made thence to the east and west for a distance of 140 feet. High-grade pyrolusite was encountered; and test shipments to works in the United States and Canada yielded satisfactory results. A concentrating mill is in course of erection preparatory to the early inauguration of shipping operations.

NEW BRUNSWICK.

The mining operations in the Province during the past year have been practically confined to the raising of coal in the Grand Lake District, and to a lesser extent at Beersville, Kent County; to mining iron ore; to the quarrying of gypsum and to tapping the natural gas supply in Westmoreland County.

Coal.—The coal shipped by rail from the Grand Lake District amounted to 40,756 tons as against 41,079 in 1910. That shipped from Beersville was 5,963 tons compared with 5,993

tons last year. No account is kept of Grand Lake coal shipped by water.

Iron.—Iron mining in the Province is confined to the operations of the Drummond Mines Company near Bathurst, and the following is a brief report of the progress of this industry prepared by the company's chief engineer, Mr. W. F. C. Parsons:—

"The townsite of Drummond Mines has been surveyed. The population of Drummond Mines numbers now about five hundred souls. One hundred and fifty acres of land have been cleared in the vicinity of the works as a precaution against forest fires. A water and fire protection system has been installed in the lower part of the town, and an electric light system has also been provided.

"Mining operations have been carried on continuously since the first of the year, employing on the average about 150 miners and about 40 men on construction work. Unskilled labour is paid at the rate of $1.75 per day of 10 hours and mechanics from $2.00 to $3.00 per day of 10 hours. The sum of $77,321.53 has been paid out in wages since the first of the year; 85,741 tons of ore have been mined; 34,272 tons of ore were shipped last season to various furnaces at Philadelphia. A concentrating mill with a capacity to treat 750 tons of iron ore per 10 hours has been erected at the mines at an expenditure of $80,000. This will be ready for operation in April, 1912. Engineers have been engaged to procure data with the view of developing sufficient water power at the Nepisiguit Narrows to supply the mines with electric energy to operate the machinery. It is the intention of the company in the near future to develop about 2,000 h.p. at this site. The site is about 3½ miles up the Nepisiguit River from the mines.

"Mining operations were suspended during the winter, the men being employed in stripping No. 1 deposit preparatory to open quarry work next season. At present about 10,000 cubic yards of stripping is averaged per month.

"Rail facilities are provided by the Northern New Brunswick and Seaboard Railway, which connects the mines with the Intercolonial at Nepisiguit about four miles south of Bathurst. Three passenger trains a week are operated on this line.

"The New Brunswick docks and terminals plant at the shipping point, at Newcastle, N.B., consist of a 10,000 ton ore pocket which delivers the ore into a bucket conveyor having a capacity of 3,000 tons per hour. The conveyor delivers the ore into a chute built on a crib-piled dock 120 feet x 50 feet. The chute delivers into the vessel."

Gypsum.—The industry formerly carried on at Plaster Rock on the Tobique River has been revived under the management of Mr. Kennedy Stinson, of Montreal, who has acquired the mining rights at that place and who reports as follows:—

"On or about April 1st, 1911, we commenced operations at Plaster Rock and have been quarrying and shipping gypsum since that date. To date we have marketed over 10,000 tons of crushed gypsum and land plaster. The crushed gypsum has been shipped to Montreal and Ottawa for use in manufacturing Portland cement. We have shipped land plaster to the experimental farm at Ottawa, and have also shipped throughout New Brunswick."

The gypsum works at Hillsboro, Albert County, continue as one of the staple industries of the Province. During the year about 65,000 tons of rock were quarried by the Albert Manufacturing Company. A new mill of daily capacity of 1,000 barrels is meanwhile being built to replace the works destroyed by fire.

Oil Shales.—The development of the shale industry is being followed with interest in the expectation that some of the success which has attended the working of the shale seams of Scotland will be attained. Heretofore the industry in New Brunswick has not gone beyond the experimental stage.

The operations of the Maritime Oilfields, Limited, at Stony Creek, Albert County, included the sinking of seven wells to depths varying from 1,206 to 2,175 feet. While all the wells do not produce gas, three are capable of supplying about 22,000,000 cubic feet per day. Pressure at well's mouth varies from 175 to 550 pounds per square inch. Crude oil raised during the year was 2,428 barrels and total gas yield was 57,000,000 cubic feet per day. A loading rack with 250 barrel loading tank has been erected at Weldon on the Salisbury-Harvey Railway, from

which point oil is loaded into tank cars for shipment. The natural gas is piped to and sold in Moncton. The oil wells are pumped regularly, the company having a regular market for the crude oil produced. The amount expended by the Maritime Oilfields, Limited, in its operations in New Brunswick since the commencement of drilling to the 30th of September, 1911, is $172,574.94.

Tungsten or Wolframite.—Valuable ore has been discovered in the northern part of York County near the Miramichi River and development has been commenced.

BRITISH COLUMBIA IN 1911.

Mr. E. Jacobs, commenting on the estimate of mineral produced in British Columbia during 1911, as contained in an official report by Mr. W. Fleet Robertson, the Provincial Mineralogist, called attention to the fact that there was a considerable disparity between the figures here presented and those prepared by the Dominion statistician as regards, in particular, lead production. He expressed the view that some agreement should be reached between the Dominion and Provincial officials to provide in future for a uniform method of compiling mineral statistics. Mr. J. McLeish remarked in reply that this was a question that had been already frequently debated by the Institute, and that he was in thorough sympathy with Mr. Jacobs' suggestion. He explained the disparity particularized by showing that the Dominion Government returns of lead production, represented the actual quantity and value of refined lead produced in British Columbia; whereas the Provincial estimate, he presumed, was based on the lead contained in the ores at the mines. Both statements, therefore, were accurate; but the one was a "mine statement" and the other a "smelter statement."

Mr. JACOBS then read the following extracts from the official report:—

"The accompanying table shows an estimated mineral production during 1911 of a total value of $23,211,816. If the revised statement of production, to be made up after receipt of returns from the operating mines and reduction-works of the Province, shall show this estimate to be approximately correct,

as it is believed they will do, it will then be seen that the total value of production in 1911 will be about $3,165,250 less than that of 1910, and less by a different amount than that of each other year since 1905.

"The comparatively large decrease in value here shown is not, however, an evidence of retrogression, for the mining industry of the Province most assuredly continues to make substantial progress, notwithstanding the diminution in production noted here. The curtailment of output is clearly attributable, for the most part if not entirely, to the effects of the strike of coal-mine employees in the Crow's Nest District, South-east Kootenay. The suspension of work at the mines and coke-ovens lasted for practically two-thirds of the year, and prevented production of coal and coke during that period to an extent that involved a decrease in value from East Kootenay alone of nearly $3,000,000. If to this be added the decrease in value of production of metals of one copper-producing company alone—as compared with 1910, of $1,600,000—which was the direct result of cutting off the supply of coke for its blast-furnaces, there will be obtained a total decrease of more than $4,500,000, which was an immediate consequence of labour difficulties at the Crow's Nest collieries. There were other temporary obstacles to production being maintained at normal rate, which in much smaller degree also accounted for a decrease in output on minerals last year, but these have either already been overcome or are in a fair way of being removed shortly. Meanwhile a settlement has been made of matters that were in dispute between the coal-mine operators and their employees, and by the end of 1911 output of coal and coke was being gradually restored to its average rate.

"It is of interest to note, in passing, that British Columbia's proportion of the mineral production of the whole of Canada is comparatively large. The aggregate value of the production of this Province to the end of 1911 is, approximately, $397,000,000, but since the published official records of that of the whole Dominion do not include production prior to 1886, the present comparison must be confined to the period of twenty-six years—1886-1911. Placing the aggregate for the whole of Canada at $1,245,000,000 (which allows for 1911 a Dominion

total of $115,000,000, an amount $10,000,000 greater than that of 1910), and British Columbia's proportion for the same period at $333,000,000, it follows that this Province has to be credited with nearly 27 per cent. of the value of the mineral production of the whole of Canada in the twenty-six-year period under notice.

"It is a striking fact, as indicating the substantial increase in the value of the mineral production of the Province in recent years, as compared with that of only a few years ago, that nearly 37 per cent. of the $333,000,000 mentioned above as the aggregate of production for twenty-six years is to be credited to five years, 1906-1910, while more than half—about 51.3 per cent.—was produced during the seven years, 1905-1911.

Mineral Production for Two Years, 1910-1911.

"The following table shows the quantities and value of the several minerals produced in the year 1910, and the estimated production in 1911. It may here be explained that the prices used in calculating the estimated value for 1911 of silver, lead, copper, and zinc are the average prices for the year, as published in *The Engineering and Mining Journal,* New York, less a deduction of 5 per cent. off silver, 10 per cent. off lead, and 15 per cent. off zinc.

	1910.		1911.		Increase.	Decrease.
	Quantity.	Value.	Quantity.	Value.		
Gold, placer, oz.	.....	$ 540,000	.....	$ 468,000	$	$ 72,000
" lode, oz.	267,701	5,533,380	225,083	4,652,465	.....	880,915
Total gold	.....	$ 6,073,380	.....	$ 5,120,465	.....	$ 952,915
Silver, oz.	2,450,241	1,245,016	1,921,300	972,946	.....	272,070
Lead, lb.	34,678,716	1,386,350	27,975,000	1,113,405	.....	272,945
Copper, lb.	38,243,934	4,871,512	39,500,000	4,890,100	18,588	.....
Zinc, lb.	4,181,192	192,413	2,600,000	127,400	.....	65,073
Total metalliferous	.....	$13,768,731	.....	$12,221,316	.....	.....
Coal, tons, 2,240 lb.	2,800,046	9,800,161	2,435,000	8,522,500	.....	1,277,661
Coke, " "	218,029	1,308,174	77,500	465,000	.....	843,174
Building materials etc.	.....	1,500,000	.....	2,000,000	500,000	.....
Total value of production.	.....	$26,377,066	.....	$23,214,816	.....	.....

Summary:—

Decrease in metalliferous minerals.....	$1,544,415
Decrease in coal and coke.....	2,120,835
	$3,665,250
Less increase in building materials, etc...	500,000
Net decrease in year's production.....	$3,165,250

NOTE.—The decrease in the production of coal, coke, lode gold, and copper is directly attributable to the strike in the Crow's Nest District, and so also, in part, is the decrease in silver, since both gold and silver occur in association with the copper in the ores from the Boundary District, where the great decrease in copper took place. A great part of the decrease in silver and in lead and practically all of the decrease in zinc is accounted for by the continued disadvantage in the Slocan, brought about by the destruction, in the summer of 1910, of mine and concentrating plants and of the railway-bridges, which facilities have not as yet been replaced. However, there is a reasonable prospect of their being in large part, if not altogether, removed during the ensuing year.

ALBERTA IN 1911.

Mr. JOHN T. STIRLING, Chief Inspector of Mines of Alberta, communicated the following information for presentation:—

Coal Production.

"The coal production is estimated in the following table:—

	Tons (short).
Crow's Nest Pass District.....	528,119
Calgary District.....	246,086
Lethbridge District.....	411,824
Edmonton District.....	497,152
Total.....	1,683,181

"The decrease in output during the year 1911, as compared with that of 1910, is attributable to the fact that a strike affecting the larger mines in the southern part of the Province was maintained over a period of 7.61 months during the year 1911.

"Sixty-nine new mines were opened in the Province during the year 1911."

Mine Accidents, 1911.

	Fatal	Serious	Slight
Edmonton District	1	7	11
Calgary District	1	4	7
Lethbridge District	..	10	17
Crow's Nest Pass District	7	32	45
Total	9	53	80

REPORTS OF BRANCH SECRETARIES.

At the invitation of the President, the Secretaries of the several branches of the Institute present at the meeting submitted brief reports of progress as follows:

Western Branch, represented by Mr. E. Jacobs.—This branch has at present a membership of between 220 and 230, of which about 40 are resident in Alberta, 180 in British Columbia, and 10 in Washington. Our meetings—usually three annually—are never held consecutively in the same centre. Since the membership is scattered over a large area the present has proved to be the only practicable course of securing adequate attendances. Mr. Jacobs expressed his thanks for the invitation extended to him to attend the annual meeting and added that he believed the Western Branch would continue to be a source of strength to the Institute.

Porcupine Branch, represented by Mr. A. H. Smith.—The branch was established in December, 1911, and has a membership of approximately 75. It is proposed to hold ten meetings during the year. Several meetings have already been held, and in each case the attendance was large, and the discussions interesting. Members generally are determined that the branch shall be a success.

Toronto Branch, represented by Mr. W. E. H. Carter.—Four years ago the Toronto Branch was small and inactive. The attendance at meetings was rarely over ten or fifteen. To-day the membership is about one hundred. Meetings are held at fortnightly intervals in the commodious quarters of the Engineers' Club and are invariably well attended. The value and interest attaching to these meetings is unquestionable. The branch entertains visitors, representative of the industry or profession from all parts of Canada and from many foreign countries. It endeavours to keep in touch and to co-operate with other branches in forwarding the welfare and work of the Institute, especially by the promotion of discussion of questions of timely economic interest. Thus, for instance, several meetings have been devoted lately to consideration of proposed legislation dealing with "Workmen's Compensation," and the views of the Toronto members thereon have been transmitted to other Ontario branches at Cobalt, Porcupine and Sudbury, with the purpose of arriving at, so far as possible, an unanimous expression of opinion of the Ontario members of the Institute directly interested in or affected by legislation in this direction. A further and essential purpose served by the branch is the establishment of new friendships; the sustaining and rejuvenation of old ones is also attained.

Montreal Branch, represented by Dr. A. E. Barlow.—The membership of the Montreal branch is between 80 and 90. Meetings are held from time to time, as occasion requires, frequently with hospitable or social intent; or again, when it is desirable that the members should have an opportunity of discussing any matter of importance affecting the interests of the Institute.

Eastern Townships Branch, represented by Mr. J. J. Penhale (Chairman).—This branch has a membership of between 35 and 40. A number of interesting and well attended meetings have been held at which papers have been presented on subjects of a practical nature relating to local mining problems. These meetings have proved very beneficial and the branch unquestionably serves a most useful purpose.

MINE RESCUE APPARATUS.

The Secretary, Mr. H. MORTIMER-LAMB, called attention to the fact that rescue apparatus for use in mines was dutiable, while other life saving appliances were not subject to such impost. It is true, he remarked, that importers were refunded the duty on application; but this envolved an interminable correspondence and delay, so much so that when spare parts were imported no attempt was made to obtain a refund of the duty. Some time ago the Western Branch of the Institute had requisitioned Government to place mine rescue apparatus on the free list and had received assurances that the concession would be granted; but no action had been taken. He, therefore, suggested that the Institute should again call the attention of the authorities to the matter.

Dr. J. BONSALL PORTER then moved that the Council of the Insitute memoralize the Dominion Government urging that rescue apparatus for use in mines be admitted into Canada free of duty. In seconding the resolution, Mr. E. JACOBS stated that British Columbia was the only province of the Dominion, wherein colliery operators were compelled by law to install rescue equipment. The Province, moreover, had established Government rescue stations.

The motion was carried.

WEDNESDAY AFTERNOON SESSION.

3 p.m. to 6 p.m.

At this session the following papers were presented and discussed: "FUEL PROBLEMS OF THE PACIFIC," by H. FOSTER BAIN, of San Francisco, Cal.; "COAL IN WESTERN CANADA," by E. JACOBS, Victoria, B.C.; "INTERNATIONAL COAL COMPETITION" (Abstract by the Secretary), by ALLAN GREENWELL, London, England; "ON THE OCCURRENCE OF MANGANESE AT NEW ROSS, NOVA SCOTIA" (presented by Dr. H. Ries), by H. E. KRAMM, Ithaca, N.Y.; and "THE TUNGSTEN DEPOSITS OF NOVA SCOTIA" (presented by Dr. T. L. Walker), by V. G. HILLS, Moose River, N.S.

WEDNESDAY EVENING SESSION.

8 p.m. to 10.30 p.m.

An interesting lecture, illustrated by lantern slides, was delivered by Dr. W. H. Tolman, of New York, Director of the American Museum of Safety, on the subject of "Accident Prevention, or the Conservation of Human Life," following which a resolution, moved by MR. DAVID H. BROWNE, was adopted, urging the Department of Mines of the Dominion, to undertake a propaganda with a view to educating both mine employers and employees in the more general observance of precautionary measures to minimize the risk of accidents.

Other papers presented at this session were: "SANITARY CONDITIONS IN MINING CAMPS," by C. H. HAIR, M.D., of Cobalt, Ont., and "THE COAL RESOURCES OF THE UNITED STATES," by E. W. PARKER, of the United States Geological Survey, Washington, D.C.

THURSDAY MORNING SESSION.

10 a.m. to 1 p.m.

The Government of Ontario, having announced its intention of introducing a Bill at an early date dealing with the subject of Workmen's Compensation and Employers' Liability, it was deemed expedient that advantage should be taken of the occasion of the annual meeting of the Institute to provoke an expression of opinion on the principles upon which such legislation should be based. The President, therefore, invited a general debate thereon, of which the following is a report:—

WORKMEN'S COMPENSATION AND EMPLOYERS' LIABILITY.

Mr. C. A. O'CONNELL (Manager Trethewey Mine, Cobalt, Ont.):—It is, of course unnecessary to point out that legislation in this direction will have an important bearing on the mining industry. The subject has already been discussed at meetings of the Cobalt Branch of the Institute and of the Temiskaming Mine Managers' Association. This latter organization was formed some five years ago, having as its object the improvement of the operating conditions at Cobalt and the pro-

motion of the welfare of the industry in general. Among those who have given careful consideration to the subject now under discussion, I may mention Mr. T. R. Jones, the manager of the Buffalo Mine, Mr. Hugh Park, the manager of the Nipissing Mine, Mr. R. R. Rogers, of the Coniagas Mine, and myself. We endeavoured to systematize our investigation so far as possible. Our labours in this respect were greatly facilitated by the information contained in a volume entitled 'Workmen's Compensation Act' and issued about a year ago by the United States Bureau of Labour and Commerce. This work presents exact data in respect to the Workmen's Compensation Laws of nearly all the countries of the world. This, and other information was correlated and compiled in the form of a report for submission to Sir William Meredith, the Commissioner appointed by the Government to take evidence preliminary to the drafting of a Bill. Sir William visited Cobalt on December 14th of last year, and presided at a hearing in the Town Hall. There was a large attendance, of which, possibly sixty per cent. were working miners. For the information of members here I shall read from my notes of the proceedings at this hearing:—

The Commissioner, after stating the object of the meeting, said he would be glad to receive suggestions from any person present. He had been appointed by the Lieutenant-Governor to study the various Acts relating to compensation and also to obtain the views of the various labour interests affected.

Mr. Ware said he represented the Western Federation, the Porcupine, South Lorrain and Cobalt branches of the Miners' Union. He claimed that the new Act should provide liberally for all manner of accidents caused in any manner whatsoever, as well as for "occupational diseases." Burden of payment to rest on employer. State insurance similar to Norway. State or Province to provide funds for the establishment of the system and to maintain this by a tax on industries. An employee who through gross carelessness is alone directly responsible for injury to himself should also be entitled to the same compensation as he would receive in other circumstances. He submitted figures to indicate that the tendency throughout the world was for the provision of State Insurance. The ordinary requirements of the English Act were good, but insurance should be compulsory. The rating of hazardous risks should be very high to induce employers to provide all reasonable safeguards and then allow a reduction therefor on subsequent premium rates.

The Commissioner stated that in the State of Washington there is a graduated tax rate for employers and when they have paid this to the State they are released from any obligation in respect of accidents.

The question as to how the Government could collect the tax was raised by the Commissioner. A miner remarked that the Government was able to collect other taxes without much difficulty and that it could and should make proper provision in this case.

Another representative of the Miners' Union expressed the opinion that mine-owners took out policies with insurance companies as the easiest method of avoiding a responsibility. In the event of a disaster, it thus devolved on the insurance companies to contest the claims of the injured, or of those dependent on them, for compensation. The Miners' Union would, at any rate, insist that in any circumstance there be compensation for injury. If the law provided that employers were not liable for injury resulting from wilful disobedience or gross negligence, employers would unquestionably take undue advantage of the provision.

A miner named Maguire endorsed the views of the preceding speaker, adding that some method of settling disputes, other than by recourse to law, should be devised. He believed the law courts were on the side of capital, and the labouring man, therefore, could not get justice.

The Commissioner took strong exception to this allegation.

Mr. A. A. Smith said that employers should only be called on to pay compensation proportionate to the nature of the original injury. It frequently happened that by inattention, or in consequence of insanitary conditions, serious complications followed mere trivial injury. If, therefore, an employer were compelled to compensate for disability in such circumstances, the patient should be under his control and supervision until recovered.

Replying to a question put to him by the Commissioner, Mr. Ware, representing the unions, said the Act as approved by them would replace the common law at present governing the matter.

Mr. O'Connell remarked that employers were as desirous as employees that a Compensation Act providing for an easy and inexpensive method of settling claims, should be placed on the Statutes. He made the further statement that the Provincial Inspectors of Mines were grossly underpaid. In his judgment the principal duty of inspectors should be to ensure that every possible device was employed in mines to guard dangerous places; that all machinery, appliances, ways, etc., were made safe; and that methods in general were kept up-to-date. This would tend to decrease the number of accidents. Mr. O'Connell stated that in the Cobalt district there was no conflict between capital and labour. The men, as a whole, were very well satisfied. Among them skilled workers were numerous, and they were well paid accordingly.

Mr. Whalen, of Elk Lake, intimated that an important step towards minimizing mine accidents would be to refuse to employ men for responsible

positions, such as those of "shift boss," "hoistmen" and the like, unless they could prove competency.

Mr. S. Cohen said the high wages paid to miners was based to a considerable extent on the risks attending the employment. Unskilled men, obtaining employment by misrepresentation, increased the risk of their fellow-workmen.

Another representative of the local union favoured many of the provisions of the Russian Act.

The Commissioner enquired whether the concensus of opinion was favourable to the appointment of local tribunals for the final settlement of all claims.

The representatives of miners replied in the affirmative; but considered that there might be difficulty in securing the services of suitable men to serve in this capacity.

It was suggested that such a tribunal might well be composed of the manager of the mine at which the accident occurred, a representative of the miners appointed by themselves, and a third arbitrator appointed by the Government.

Mr. B. Neilly remarked that in the matter of compensation for "occupational disease," a difficulty arose in fixing the responsibility, consequent upon a man moving from one employment to another.

The Commissioner expressed belief that in some countries provision was made covering this contingency by requiring the respective employers to contribute equally towards payment of the claim.

The representative of the Mine Managers' Association advocated the passage of a comprehensive measure based on the fundamental principles of the New Zealand Act, and incorporating the Russian percentage table in respect of accidents and the Norway classification of risks. He approved of the principle of insurance under either State or corporation auspices; and also advocated the inauguration of a more thorough system of inspection; the trial of all disputed claims by a District or County Judge, at the nearest convenient spot to the scene of the accident, and would provide that appeal could not be carried beyond the Divisional Court. He pointed out the importance of conciseness and clarity in the wording of the Act, especially as regards the settlement provisions, and recommended that minimum and maximum compensation in the case of death or of total disability, be fixed at $1,000 and $2,600 respectively, in conformity with the Russian Schedule; and advised that the compensation in the case of injury resulting from culpable negligence or wilful disobedience should be fifteen per cent. of the established amount. He stated, in conclusion, that the percentage of accidents in the Cobalt mines was very low.

Mr. C. A. O'CONNELL (continuing): "The majority of the operating mines in Cobalt carry 'Employers' Liability' insurance. One of the large mines, however, refrained, by way of

experiment, from doing so for one year, and during that period paid out in claims for injury, a sum of less than $250 in the aggregate. Of course, had any serious accident or accidents occurred within the twelvemonth, the experiment might have proved a costly one. The following returns from twelve mines, at Cobalt, covering a period of twenty-two months, from January 1st, 1910, to November 1st, 1911, afford some information of results under the present system:

Average number of men employed.....	2,021
Average wage per annum per capita.....	$869.00
Total amount of wages paid for 22 months...	$3,263,788.00
Average premium rate.....	$2.12
Total premiums covering 22 months.....	$69,257.37
Insurance compensation paid (allowance made for suits pending)	$20,490.04

"By the provision of the proposed Act, endorsed by the Association, the aggregate amount payable in compensation would represent $40,341.40. I believe no employer of labour in the Cobalt area is opposed to the passage of a just compensation measure. Inasmuch as the majority of the mining companies already carry insurance, as already stated, it is estimated, that the suggested statutory requirements would have the effect of slightly reducing our present outlay on accident policy account.

"Mining, of course, is a hazardous calling, and this should be taken under consideration in the drafting of a Bill providing for Workmen's Compensation. I have a memorandum of the total number of accidents in mines at Cobalt, covering a period of twenty-two months:

Incapacity for less than 8 days.....	84
Incapacity for more than 7 days and less than 15 days.....	32
Incapacity for more than 2 weeks and not over 4 weeks.....	28
Incapacity for between 4 weeks and 8 weeks....	9
Incapacity between 8 and 26 weeks.....	6
Permanent and total incapacity	2

Permanent and partial incapacity	3
Resulting in death	11
Total	175

Ratio of accidents to number of men employed, covering period of one year.....1 in 21

"During the first two or three years of mining operations at Cobalt the precautionary measures for the avoidance of accidents were less thorough than since that time. At present, as a result of more careful inspection and of greater care and attention on the part of managers, hazards in this camp have been reduced to a minimum. We have at Cobalt a very excellent hospital, under the control and supervision of the mining companies. Each company, moreover, has its own medical service. At present the patients in Cobalt hospital number seven only.

"The following memorandum, approved by the Cobalt Branch of the Canadian Mining Institute, and by the Mine Managers' Association, includes recommendations which it is desired should be incorporated with such legislation as may be adopted dealing with the subject of 'Workmen's Compensation:'

1. The Association represents practically all the producing mines—approximately twenty-one.

2. It is admitted that the companies have a responsibility in regard to every employee, even in cases where death or total incapacity results from accidents for which the employee is guilty of contributory negligence. Hence it is recognized that those dependent on such employee should receive some compensation. They merely require that the scale of compensation, varying according to circumstances, should be reasonable and fair.

3. It is submitted that there is a distinction between the metal mining industry and ordinary manufacturing industries. If a Workmen's Compensation Act bears heavily on a manufacturing industry such an industry can add the extra cost to the price of the output and the consumer will pay the additional cost. The silver mine owners have no power to control the price of their output, and if too heavy a burden is placed on them by the Workmen's Compensation Act, there will be a possibility—if not probability—of reimbursing themselves to a certain extent at least by reducing the wages of the employee. Too liberal a measure might, therefore, work to the disadvantage of the employee.

4. In dealing with the mining industry, it would be advisable, if practicable, to differentiate between the metal mining industry and other

industries; and to protect the employers from too great negligence on the part of the employees. Rigid and frequent inspection of the mines by a Government Inspector should be provided, the expense to be borne by the Government.

5. The Association suggests that in the main the principles of the New Zealand Worker's Compensation Act (1908) should be adopted, but instead of the schedule appended to the New Zealand Act, the schedule appended to the Russian Act of 1903 should be adopted. Other modifications as hereafter suggested should be adopted.

6. Where death or total incapacity results from an accident, the employee's dependents should receive three times the actual annual earnings of the deceased, but in no case less than one thousand dollars and not more than two thousand six hundred dollars (average annual wage of an employee in the Cobalt Camp about eight hundred and sixty-nine dollars). In the case of partial dependence, the compensation should not be more than thirty-three and one-third per cent. of the above.

7. During the period of total incapacity the weekly payment (if any) to be provided shall not commence until a period of seven days shall have elapsed after the accident and shall be at a rate of fifty per cent. of his actual average weekly earnings; but in no case shall the total amount exceed the sum of the death maximum, and in case of death resulting, the weekly sums remitted shall be deducted from the amount to be paid to the dependents.

8. The Act shall apply only in case of accidents. No compensation should be allowed for diseases, contracted during period of employment as provided in the New Zealand Act.

9. The principal and his contractor shall be jointly and severally liable for accidents to employees while in the employment of the contractor, but the contractor shall indemnify the principal.

10. Compensation according to schedule shall be paid whether the employee can prove negligence or not on the part of the employer. In case the employer can prove gross or wilful negligence on the part of the employee, the employee shall receive no compensation; but in case of his death his dependents should receive fifteen per cent. of the amount he or they would otherwise receive.

11. In the event of the parties being unable to agree upon what scale compensation should be made or upon any point in dispute under this Act, it shall be adjudicated upon by the County or District Judge, who shall upon the application of either party, appoint a day for a hearing of the issues in dispute. Such hearing shall be held at the most suitable place nearest to the place where the accident occurred.

12. All sums of money paid either by agreement or under a Judge's ruling in the case of death shall be paid into the County or the District Court and shall be apportioned by the Judge of such Court among the dependents.

13. There shall be the right of appeal from the County or District Court to the Divisional Court. Neither party shall have a right of further appeal.

14. If within the power of the Provincial Legislature it should be provided that the employee or his dependents, in case of his death, shall have no right of action at common law.

"At the hearing at Cobalt, Sir William Meredith had remarked that in the adjudication of claims for compensation he was at first inclined to the opinion that the common law would continue to prevail, but after further consideration he had reversed this judgment."

Mr. DAVID H. BROWNE: "As the representative of the largest mining industry in Ontario I wish to make a few comments in the nature of a minority report. We have carefully considered this matter and there are certain things in which we disagree with the Mines Association. We believe that the best features are contained in the Workmen's Compensation Act of the State of Washington. By this Act all industries in the State involving risk to the employee are classed into certain groups, each paying to the State a certain percentage of the amount they pay for labour. This percentage is based upon the ascertained risk of that class of employment in which they stand. For example, the percentage paid by certain classes is as follows:—

Shaft sinking	.060
Blast furnace	.040
Coal mines and smelters	.030
Mines other than coal	.025
Powder works	.100
Creameries, etc.	.015

"These percentages are determined by the number of accidents in the various classification for the previous year and are automatically increased or decreased to meet the risk.

"There are appointed by the Governor, three commissioners, holding office for six years, one retiring every second year. These commissioners settle all claims for damages due to death or injury, in accordance with certain general rules laid down in the Act. In case of the death of the head of a family, by accident, occurring at his work, the widow receives $20.00 per month for

herself during her lifetime and $5.00 per month for each child under legal working age. There are certain provisions for commutation of this payment in case of her re-marriage or for settlement of claims by a lump payment.

"Injuries not resulting in death are provided for by a regular classification of such injuries, but the Act is flexible enough to allow a certain exercise of their own judgment on the part of this commission.

"The strong point of the Act is that it places the burden of insurance where it belongs—on the industry and on the employer. No payment whatever is made by the men. On the other hand while the Act very carefully specifies that all possible measures of safety must be taken, and while it heavily penalizes any employer not using all due precaution in his business, still it realizes that there are in all employments certain risks incident to the industry and absolutely beyond the control and beyond the personal responsibility of the employer.

"Under the present law we do not know where we stand. Under whatever regulations there are at present, the employer is presumed to be negligent unless he can prove the contrary. This is not just. We have experimented with Employers' Insurance and abandoned it, because in case of accident the workman had to fight out the matter with the insurance company and by the time the affair was settled there was very little left for him.

"We prefer to take a more personal view of the situation. When a man is injured we try to settle the claim so that he will feel that he has been justly treated. We inquire into the circumstances—not simply of the accident, but of those dependent on the injured man. So far, by a humane view of this subject; by a conscientious endeavour to do the right thing, we have been very successful in avoiding lawsuits.

"But there always remains this feature. At the present time no matter what position we take or how anxious we may be to make a proper settlement, we can always be forced by some pettifogging lawyer to defend ourselves in a suit under the common law. Of course, the lawyer holds out to the injured man the bait of an immense sum in payment of damages. Need-

less to say, if such damages were recovered, a very large amount would go to the lawyer. We have in the past had to defend a few such suits, and I desire to say here that I know of no position more degrading than to be forced in open court to oppose some poor cripple whose injuries were due to no negligence on our part, whose interests we have endeavoured to safeguard, and whose claims we have already offered to settle in a most liberal manner.

"I repeat that this position is a degrading one. There is a certain risk incident to the business. We realize this, and we realize that insurance against this risk should be paid by the industry and not by the employee. You may object that the employee should pay a certain portion of this insurance, just as you and I carry life and accident policies. You may say that the labourers are paid in proportion to the risk they undergo.

"As to the first proposition. These workmen do, in all large companies pay an insurance. This insurance is, however, entirely in their own hands. In our case there is an Employees' Accident Association to which all employees belong. This is managed by a committee of the men themselves. It is entirely a mutual affair. From this association each man receives a certain amount in case of injury, or in case of death his widow receives five hundred dollars. This, however is apart from the issue. I am speaking of the claim always made on any company in case of death or injury of their employees.

"As to the fact that men employed in such work as mining and smelting receive higher wages than those employed in less dangerous occupations and for this reason they should bear a portion of any state or provincial insurance, I have only to say that such views are entirely logical and correct in theory, but they will not work out in practice. You cannot dodge this fact; no matter what wages you pay; no matter what accident association your men belong to; there is always in case of death or injury a claim upon the employer. We do not seek to avoid it. We do wish to have the matter placed in the hands of a commission whose entire business shall be the study of this subject,

whose decisions shall be based on a knowledge of the facts, and whose findings shall be final.

"We have found that the closer our relations with our men the more satisfactory is the conduct of the business. I, therefore, urge the study of the Workmen's Compensation Act of the State of Washington, as containing what we believe to be the correct solution of this important question."

Mr. THOMAS W. GIBSON: "Will Mr. Browne inform us how long the Act to which he refers has been in force in the State of Washington?"

Mr. BROWNE: "It went into force last year. A test case was tried under its provisions and the Act was admitted as being entirely constitutional."

Mr. GIBSON: "I asked the question in order to bring out the information regarding the status of this legislation in point of time. My attention has been directed to some very adverse criticisms of the Washington Act. It has been stated that it has been the cause of letting loose on the State Treasury a veritable flood of claims, and there is a likelihood of its repeal on that account."

Mr. A. J. YOUNG: "In view of the great importance of the issues envolved I beg to move that the President appoint a committee to thoroughly sift the facts and submit a resolution for the consideration of members at a later session."

The motion was seconded by Mr. R. R. HEDLEY and adopted.

The President nominated the following gentlemen to serve on the committee: Messrs. C. A. O'Connell (chairman), David H. Browne, C. V. Corliss, R. R. Hedley and G. G. S. Lindsey.

The Committee, at a subsequent session, presented the following report:

REPORT OF COMMITTEE.

Your Committee, after consideration of the question of Workmen's Compensation, beg to report as follows:

(1) That the working of the Compensation Act be placed in the hands of a Commission to be appointed by the Crown.

(2) This Commission shall collect a definite amount from

each mining company, based upon the monthly pay roll and proportionate to the risk incident to the business.

(3) This amount should be contributed by the employers, and should not be collected directly or indirectly from the employees.

(4) The distribution of this fund shall be in exclusive control of the Commission, from whose decisions there should be no appeal to ordinary Courts.

(5) There shall be no liability except under the Act, all common law liability to be expressly excluded.

(6) We recommend the consideration of the principles of the Workmen's Compensation Act of the State of Washington, Chapter 74, of 1911, and also the New Zealand Act with the Russian schedule of payments, and the Norwegian classification.

All of which is respectfully submitted.

(Signed) C. A. O'CONNELL,
Chairman.

The report was presented by the Chairman of the Committee, who stated it was generally understood that legislation in this direction was to be introduced at the present session. In reply to a request from Mr. R. W. Brigstocke for an elaboration of the Committee's findings, Mr. D. H. Browne said:

"There are two or three points to be remembered: First, this is a provincial measure, and hence, has no application to the coal mines. Secondly, there is this possible opposition: theoretically the employee should bear a certain proportion of the tax in the nature of an insurance. We are perfectly willing to concede the principle, but we submit that it will not work out in practice. In every large mining camp the employees voluntarily support a Workingmen's Accident Fund, to which they contribute 50 cents a month; that is entirely their own matter. If they continue to carry that, no further burden is placed upon them by the adoption of our recommendations. In any case the employer always carries the liability of being sued under the common law; he is always liable for injury to his men. We are willing to shoulder the burdens we now bear, we do not ask that

any further burdens be placed upon us, we do not ask for any lessening of the burdens.

"All we ask is that when we do pay a justly graded tax according to the risk incident to our business, the matter be taken out of the jurisdiction of the courts and away from the intervention of a certain class of lawyers. We have thorough confidence in the decisions of our courts, but each court will interpret the matter in its own way—and no court has time for such careful study of the subject as a permanent commission will give it. We want the beneficiary of the injured to have the money and to have it without delay."

The motion to adopt the Committee's report was then put to the meeting and carried.

THE LATE MR. JOHN B. HOBSON.

Mr. R. W. Brock, Director of the Geological Survey of Canada, referred in feeling terms to the loss the Institute had sustained by the death, which had occurred recently in Victoria, B.C., of Mr. John B. Hobson. Mr. Hobson was, he stated, a charter member of the Institute, and had served on the Council, both as a member of the Board and as a vice-president. His career as a mining engineer was a notable one, and his achievements, more particularly those in association with hydraulic gold mining in the Cariboo district of British Columbia, had won for him a wide recognition. Mr. Brock asked permission to move that the Institute in annual meeting assembled record their sense of the loss sustained by the death of Mr. Hobson and express to the members of the family of the deceased sympathy in their bereavement.

The motion was seconded by Dr. W. G. Miller, and received a respectful assent.

READING AND DISCUSSION OF PAPERS.

The following papers were then presented and discussed: "THE EVANS-STANFIELD ELECTRIC FURNACE," by Mr. J. W. EVANS, of Belleville, Ont.; "ON THE CONCENTRATION OF IRON

ORE AT MOOSE MOUNTAIN, ONT., by Mr. F. A. JORDAN, of Moose Mountain, Ont.; "RECENT IMPROVEMENTS AND ADDITIONS AT THE CANADIAN COPPER COMPANY'S WORKS, Copper Cliff, Ont., by Mr. DAVID H. BROWNE, Copper Cliff, Ont.; and "ON CONCENTRATION OF ORES IN THE COBALT DISTRICT, ONT., by Professor R. H. RICHARDS, of Boston, Mass.

THURSDAY AFTERNOON SESSION.

3 p.m. to 6 p.m.

Upon re-assembling for the afternoon session, Dr. W. G. MILLER asked leave to move that Dr. James Douglas, of New York, be nominated a Patron of the Institute and that the Secretary be directed to communicate with that gentleman and invite his acceptance of this office.

In speaking to his resolution Dr. Miller said: "Every year at the annual meetings of the Institute we have had the privilege of having with us one who largely added to their interest. I refer to Dr. James Douglas. We all regret that Dr. Douglas is not able to be with us to-day. He has shown a great interest not only in the Canadian Mining Institute, but he has been one of the leading members of the American Institute of Mining Engineers, was President of that Institute for two years, and is also an active member of the Institution of Mining and Metallurgy of England. In addition to that Dr. Douglas's work as president and manager of important mines and his success as a metallurgist is well known to us all. I think, sir, that it would only be fitting for this meeting in Dr. Douglas's absence to show, maybe only in a small way, appreciation of what he has done not only for this Institute, but for the industry in general. I would therefore like to move, sir, that Dr. Douglas be made a Patron of the Canadian Mining Institute, and I hope that Mr. Hardman will second this motion. The election of Patrons is generally relegated to the Council, but in Dr. Douglas's case I think he would appreciate it the more if the election originated from the general meeting. I have therefore much pleasure in moving this resolution."

Mr. HARDMAN: "I have the greatest pleasure in seconding this motion as a tribute to the eminent metallurgist, Dr. Douglas. We must remember that Dr. Douglas is a Canadian first and last, whatever his services have been to the United States. I have only to add that no member of the profession is more distinguished in his own field or has a greater record of accomplishment to be proud of than the gentleman whom we desire to thus honour."

THE PRESIDENT: "It is not necessary that I should add anything to what has been said by Dr. Miller and Mr. Hardman in reference to Dr. Douglas. We all know what an admirable man he is in every respect and what a thorough Canadian he is, and how he has attained to the highest reputation in the mining world."

The motion was adopted unanimously.

Subsequently the Secretary received a telegraphic reply from Dr. Douglas accepting the office, and reading as follows:

"I appreciate keenly the honour you have conferred on me and will try to deserve it. I regret I cannot be with you, but wish you heartily good cheer."

READING AND DISCUSSION OF PAPERS.

The following papers were presented and discussed at this session: "THE DOMES OF NOVA SCOTIA," by Mr. T. A. RICKARD, of London, England; "THE ORIGIN OF THE QUARTZ VEINS OF THE PORCUPINE DISTRICT," by Dr. A. E. BARLOW, of Montreal; "ORIGIN OF THE PORCUPINE GOLD DEPOSITS," by Mr. REGINALD E. HORE, of Houghton, Michigan; "THE FUTURE OF COBALT," by Mr. CHARLES A. O'CONNELL, of Cobalt, Ont.; and "THE COPPERMINE COUNTRY," by Mr. J. B. TYRRELL, of Toronto, Ont.

CABLEGRAM FROM THE INSTITUTION OF MINING AND METALLURGY.

Prior to the adjournment, the President announced the receipt of a cable message from the Council of the Institution of Mining and Metallurgy, reading as follows:

"Assembled Council of Institution send cordial greetings to Canadian engineers and best wishes for increased prosperity of Canadian Mining Institute."

On motion of Dr. Miller, the Secretary was instructed to despatch a reply in acknowledgement of the Institution's friendly expression of goodwill.

SMOKING CONCERT.

In keeping with established custom the annual smoking concert was held on the evening of Thursday, the second day of the meeting. The programme was exceptionally good, and under the capable chairmanship of Col. J. J. Penhale, of Sherbrooke, the entertainment proved thoroughly enjoyable. The principal contributors to the programme were Dr. J. F. Kemp, Mr. T. A. Rickard, Mr. J. Parke Channing, Mr. A. M. Hay, Mr. John Birkinbine, Mr. O. E. LeRoy, Mr. J. C. Murray, and the Glee Club of the University of Toronto.

FRIDAY MORNING SESSION.

10 a.m. to 1 p.m.

The papers presented at this session were: "VENTILATION IN METAL MINES," by Mr. FRANK C. LORING, of Toronto; "INDUSTRIAL EDUCATION FOR MINERS," by Mr. F. H. SEXTON, of Halifax, N.S.; "THE MIAMI MINE AND MILL," by Mr. J. PARKE CHANNING, of New York; "CO-OPERATIVE MINING INVESTIGATION," by Mr. H. H. STOEK, of Urbana, Illinois; "THE DECREASE IN VALUE OF ORE SHOOTS WITH DEPTH," by Mr. F. L. GARRISON; and "ELECTRIC SMELTING OF ZINC ORES," by Mr. W. R. INGALLS, of New York.

FRIDAY AFTERNOON SESSION.

3 p.m. to 5.30 p.m.

At the afternoon session the presentation and discussion of papers was continued, and included "ADDITIONAL NOTES ON THE

FORMATION OF CONTACT ZONES IN LIMESTONES," by Dr. J. F. KEMP, of New York; "SOME TYPES OF ENRICHMENT BY ASCENDING SOLUTIONS IN VEINS FORMED NEAR THE SURFACE," by Mr. WALDEMAR LINDGREN, of Washington, D.C.; "THE NEWER DIABASE IN PREISSAC, JOANNE AND ADJACENT TOWNSHIPS, QUEBEC," by Dr. J. A. BANCROFT, of Montreal; and "THE ORIGIN OF THE ORES OF COBALT," by Mr. CARL REINHARDT, of Cobalt, Ont.

ELECTION OF COUNCIL, 1912.

The Scrutineers then presented their report announcing the election of the following gentlemen to offices on the Council for the ensuing term:

President.—Dr. A. E. Barlow, Montreal, Que.

Vice-Presidents.—Mr. Arthur A. Cole, Cobalt, Ont.; Mr. R. H. Stewart, Trail, B.C.

Councillors.—Mr. R. W. Brigstocke, Cobalt, Ont.; Mr. H. P. DePencier, Montreal, Que.; Mr. D. B. Dowling, Ottawa, Ont.; Mr. G. Herrick Duggan, Montreal, Que.; Mr. Charles Fergie, Montreal, Que.; Mr. W. F. Ferrier, Toronto, Ont.; Mr. W. S. Johnson, Montreal, Que.; Mr. J. J. Penhale, Sherbrooke, Que.; Mr. Chas. E. Watson, Porcupine, Ont.

[Note.—At a meeting of Council held on Saturday, March 9th, Mr. G. G. S. Lindsey, of Toronto, was elected a vice-president to serve for a term of one year; and Mr. R. W. Coulthard, of Blairmore, Alta., was elected a Councillor to serve for a like term.]

A vote of thanks was tendered the Scrutineers for their services and the proceedings then terminated.

ANNUAL DINNER.

The Annual Dinner of the Institute was served in the Ball Room of the hotel, at 7.30 p.m., covers being laid for one hundred and thirty; while in an adjoining banquetting hall a number of ladies, the wives of attending members, were similarly enter-

tained. Among the guests of the evening were Mr. T. A. Rickard, Mr. J. Parke Channing, Dr. J. F. Kemp, Capt. H. A. C. Machin, M.P.P. (representing the Ontario Government), Mr. R. V. Norris, Mr. F. L. Garrison, and Mr. Theodore Dwight. In the course of the evening, the health of the Past-President, Dr. Frank D. Adams, was proposed in a graceful speech by Mr. J. E. Hardman, who made special reference to the services rendered the Institute by Dr. Adams, not only during his tenure of office as President, but covering the long period of his association with the Institute. A most hearty acknowledgment was also made of the whole-hearted co-operation and assistance of the members of the local organization committee, under the chairmanship of Mr. W. F. Ferrier, in the arrangements for the conduct of the meeting, and to whose efforts its success was so largely attributable.

EXCURSION TO PORCUPINE AND COBALT.

For the special entertainment and instruction of guests of the Institute (including also members resident in distant parts of Canada) arrangements were made for an excursion to the new gold area of Porcupine and to the silver mines of Cobalt. The Temiskaming and Northern Ontario Railway Commission and the Grand Trunk Railway Company most generously assisted the project by consenting to make no charge for transportation, while the Ontario Government promised financial aid. A private car was accordingly chartered, and a party of eighteen left Toronto on Saturday evening, March 9th, bound for South Porcupine. The members of the party were Mr. T. A. Rickard, Editor of the *Mining Magazine,* London; Mr. R. V. Norris, of Wilkes-Barre, Pa.; Mr. F. L. Garrison, of Philadelphia; Mr. W. R. Ingalls, Editor of the *Engineering and Mining Journal,* New York; Mr. Theodore Dwight, of New York; Mr. H. W. Hardinge, of New York; Mr. H. Kehoe, of Spokane, Wash.; Mr. F. H. Sexton, Director of Technical Education, Halifax; Dr. A. E. Bar-

low, President of the Institute; Mr. R. W. Brock, Director of the Geological Survey of Canada; Dr. W. G. Miller, Provincial Geologist of Ontario; Mr. Theo. C. Denis, Superintendent of Mines of the Province of Quebec; Mr. Arthur A. Cole, Mining Engineer of the T. & N. O. Railway Commission; Mr. H. Mortimer-Lamb, Secretary of the Institute; Mr. E. Jacobs, Secretary of the Western Branch of the Institute; Mr. A. H. Smith, Secretary of the Porcupine Branch; Mr. A. M. Hay, of Toronto; Mr. W. F. Ferrier, Chairman of the Toronto Branch; and Mr. Ben. Hughes, a representative of the Toronto *Globe*.

The party upon arrival at Porcupine on Sunday afternoon visited the new forty-stamp mill at the Hollinger mine, were fittingly feasted at a camp dinner and, subsequently, conducted underground. On Monday morning, the South Porcupine Board of Trade, having kindly provided sleighs, the new mill, of steel construction, at the Dome Mines, was visited. At noon the train left for Cobalt. Here most excellent arrangements for the entertainment of the visitors had been made by a local committee, of which Mr. Norman R. Fisher was chairman. On the Monday evening the Institute was permitted to act as host. An impromptu smoking concert, attended by a number of the mine-managers of the camp, was held in the car. They left quite late. Mr. R. V. Norris was good enough, upon request, to compound and introduce a beverage popular in the Southern States where it is euphemistically entitled a "Creole Lady." It was sampled by a gentleman of the party—an eminent authority on ore sampling —and pronounced "everything a cock-tail should not be." By others, however, the refreshment was appreciated.

On Tuesday, visits were paid to the Nipissing, where a "pour" of silver was witnessed, to the Crown Reserve, the Temiskaming, the Coniagas and the Trethewey. The hospitality of the mine managers was unbounded, and not only was ample provision made to satisfy the interest of the visitors in those features which are contributory to the unique character of Cobalt as a silver-producing area, but no effort was spared to make the visit a tremendous social success.

The visit to Porcupine.—At the Hollinger mine.

The visit to Porcupine.—At the Dome mine.

At Cobalt. Three zealous and distinguished members of the party.

The visit to Cobalt.—At the Coniagas Mine.

PROCEEDINGS OF THE SEMI-ANNUAL MEETING, Victoria, B.C., and Frank, Alta., September, 1912

The first Semi-Annual Regular Meeting of the Institute was held at Victoria, B.C., on Wednesday and Thursday, September 18th and 19th, and adjourned to Frank, Alta., on Monday, September 30th.

Victoria Meeting.

The proceedings were opened by an address of welcome by Sir Richard McBride, Premier and Minister of Mines of British Columbia, who said, in part:

Premier's Address.

"Permit me to extend to you on behalf of the Government a hearty welcome to British Columbia—a province long notable for the wealth of its mineral resources.

"I have been associated for upwards of eleven or twelve years with the work of the Provincial Department of Mines and am gratified to have the assurances of mining engineers, of responsible commercial bodies in the province, of companies operating here, and of the miners themselves, that the departmental policy has been productive of generally good result. We have in the last few years given special attention to the consolidation of the laws governing the operation of coal mines, and, with the assistance of our technical heads and permanent officials, we have, I think, passed an Act which not only protects the workmen and safeguards life and limb to an extent, perhaps, not so well covered heretofore by the regulations, but at the same time gives fair recognition to the mining companies and the interests that they represent. Our Coal Mines Regulation Act, I may say, has been commended, not only at home, as I have just stated, but from States in the Union where coal mining is a prominent industry and from the Old Land complimentary references have been received. We do not assert that the legislation in itself is perfect or that it represents the last word in the way of mining regulation, but we do claim that it is immeasurably in advance of anything that has been attempted heretofore in any of the provinces of Canada.

"Before I conclude my few words of welcome this morning, I may, I think, assume that your Institute will be in complete sympathy with the Government in its anxiety to provide that mining company promotion shall be undertaken in future on right and legitimate lines only. The conditions that obtained some fifteen or sixteen years ago when the public was victimized and British Columbia's good name tarnished by unscrupulous promoters of worthless concerns, was most disastrous to the industry; and now that this industry is again flourishing and that Western mining conditions in general are improving, it is eminently desirable that we should not experience a recurrence of the unfortunate state of affairs to which I have alluded.

"Finally, may I remark that you have in Mr. E. Jacobs, Secretary of your Western branch, a very energetic and active official. It has always been a great pleasure to me and to those associated with me in the Provincial Department of Mines to work with Mr. Jacobs. We have invariably found him painstaking and anxious always to get at the truth of anything that has to do with mining in British Columbia, and ever ready to take the utmost pains to ensure the accuracy of his statements when he writes for publication. I cannot forget, too, that we have here our old friend Mr. H. Mortimer-Lamb, the secretary of your Institute, who some years ago was closely identified with mining in British Columbia. We have always followed Mr. Mortimer-Lamb's work since he left us, and we are glad to see the success he has achieved in his new field. While he is now resident some thousands of miles from British Columbia, it is fair to say that whenever opportunity offers he is only too ready to say a good word for this province.

"I thank you very much for the opportunity you have given me to address you this morning, and I trust that your deliberations, like those that have characterized all the meetings of your organization, will be fruitful of excellent results."

ADDRESS BY THE HON. WM. TEMPLEMAN.

At the invitation of the President, the Hon. William Templeman then addressed the meeting as follows:

"I esteem it a privilege to be afforded this opportunity. I regard your organization as one of the most important associa-

tions for the advancement of a particular industry that exists in Canada. During my regime, or my temporary occupation of the position of Minister of Mines for the Dominion of Canada, I had much to do with the Canadian Mining Institute. The Department of Mines was organized only four or five years ago, and, during the organization of that department, the members of the Government and myself frequently sought the advice of the Mining Institute.

"During my term of office the question arose regarding the necessity of providing a mining law for the Dominion. The Institute unanimously recommended that steps be taken in this direction, and, after a conference with the Premier and myself and others, it was determined that a mining law for the Dominion of Canada should be prepared. The Act was drafted and is ready to be submitted to Parliament. I think I am right in saying that the bill, as framed, will meet the views of the mining men of the Dominion of Canada.

"The bill was prepared by a Committee, representing the Canadian Mining Institute, under the auspices or direction of that department. This committee made a very careful study of the provincial mining laws and those of the States of the American Union, with the aim of presenting the country with an Act that would both in principle and detail be regarded as a model in legislation. It was hoped and believed that such legislation would commend itself to the provinces and would thus ultimately lead to the accomplishment of uniformity in mining laws throughout the Dominion—a consummation very much to be desired. Hence I desire to state that the steps so far taken in this direction is due to the Canadian Mining Institute. It is the great power behind the Mines Department at Ottawa at all events, and it is the power to which the department in my time looked for advice and assistance, and never looked in vain.

"It is to be hoped that the Institute will impress upon the Dominion Government the absolute necessity of completing the organization of the Department of Mines. It is most important to my mind that the Department of Mines should be made one of the leading departments of the Dominion Government. There is a strong feeling here that there should be a separate Minister

of Mines. It would be a very excellent thing if we could have a separate portfolio of mines; but the Cabinet now includes some fourteen ministers, and the Premier might not deem it good policy to add another. Nevertheless, with whatever department that of mines is allied, it should not be subordinate to the other business of that department. At the moment it is a branch of the Department of the Interior, and as such is subordinated. If, therefore, it is not deemed expedient to create a separate portfolio, the Government might, at all events, provide that the Department of Mines shall dominate the department to which it is attached. This is what really was intended under the first organization, because the Department of Inland Revenue, while very important in the sense of revenue, is less important, to my mind, in the development of Canada than is the Department of Mines.

"Several members of the present Government are well informed concerning mining conditions in Canada, and I am sure that if this powerful and representative Institute will advocate with the new minister the cause they have so much at heart they will be able to accomplish a great deal within the next year or two."

The President, Dr. Barlow, after thanking Mr. Templeman for his friendly references to the Institute, remarked that it was, of course, a non-partisan body. This was fully realized, and he had no doubt that the present Government might be depended on to further the interests of the mining industry, and would unquestionably take the resolutions of the Institute into account.

Addresses were also made by Mr. J. Beckwith, Mayor of Victoria, and Mr. J. J. Shallcross, President of the Victoria Board of Trade.

PRESIDENTIAL ADDRESS.

The President then delivered the following address:

"I find by the agenda which our Secretary has placed before me that I am expected to make a few remarks. Canada is a country of such enormous extent, and its interests are so varied and so widely separated that it is of vital importance that we should come together at times to discuss our common

problems, if the Canadian Mining Institute is to remain as thoroughly representative and national as it is at present.

"It was mainly with this view in mind, but coupled with the cordial invitation of the British Columbia members, that we decided to hold our first semi-annual meeting in Victoria. Moreover, we realized that altogether the present time of year, although it has certain disadvantages, was really the best at which to call such a gathering. Among the several matters of Institute business which should be discussed at this meeting are the proposed amendments to the by-laws, which, on the ruling of the President at the last annual meeting, were declared out of order, owing to insufficient notice. At the same meeting we were rather startled by the statement of the Secretary of the Western Branch that the Western members had not heard of these amendments until after their arrival in Toronto. In the circumstances, therefore, it is important that these amendments to the by-laws, which are to be presented to the next annual meeting by a representative committee, should receive careful consideration by all the members present at this gathering.

"I would like to remark on the continued prosperous condition of the mineral industry of Canada. The annual production shows a steady and very healthy increase. Although the production in certain sections in any year may be curtailed, such decrease is more than compensated by a corresponding increase in other portions of the country.

"In Nova Scotia, I regret to say that, in spite of repeated attempts to rehabilitate gold mining, the industry continues to decline, and I very much doubt if we can hope in the near future for any large revenue from this source to swell the annual production. The decrease in gold mining, however, serves in a measure to direct attention to the large increase in the production of coal, which this year will be the largest in the history of the province.

"New Brunswick has not yet attained to an important position as a mineral-producing province, although there is promise of the establishment of an iron industry of substantial proportions in the Bathurst District. The oil and gas found near

Moncton will soon be utilized to build up a large industrial centre at that place.

"The Province of Quebec shows a steady and substantial increase in mineral products. In 1899 the value of these amounted to $2,585,635, while in 1911 this value had increased to $9,087,698, or 251.5 per cent., a proportional progress only exceeded by that of Ontario in a similar period (334.5 per cent.). The recent very large addition to the territory of Quebec, most of which is underlaid by rocks of pre-Cambrian age, gives promise of much larger proportional increase. Until lately Quebec comprised an area of 352,000 square miles. This area, in May, 1912, was more than 706,834 square miles by the addition of Ungava. Only a very small proportion of this territory has been explored by prospectors. In spite of over-capitalization and over-production in the asbestos industry of Quebec, the shipments in 1911 were higher than in 1910, although the quantity of rock mined was 13.10 per cent. less in 1911 than in 1910. A proportion of the shipments was drawn from stocks in hand. In 1910, 80,605 tons were shipped, valued at $2,667,-829, while in 1911 this amount had increased to 102,224 tons, valued at $3,026,306. The balance between output and shipment is slowly readjusting itself, so that there is a notable improvement in the asbestos situation. Quebec now contributes more than 75 per cent. of the world's total production of asbestos. Quebec has also the unique distinction of having the deepest copper mine in Canada, the Eustis Mine being now down nearly 3,000 feet on the slope. The copper situation is improved, too, by the addition of the McDonald Mine at Weedon to the list of shippers. This mine is now producing at the rate of over 2,000 tons per month of ore, which averages over 42 per cent. of sulphur and 5 per cent. of copper, with negligible quantities of gold and silver.

"Ontario has now taken her place as premier province in mining of the Dominion, having passed British Columbia about three years ago. The production, which, in 1909, amounted to $32,981,375, grew to $39,313,895 in 1910, and $42,672,904 in 1911. If this same rate of growth is maintained the value of the mineral production for 1912 will be over $45,000,000. For

the twelve years, ending in 1911, the proportional increase has been 334.5 per cent., while in the same period British Columbia shows an increase of 67.9 per cent., and the whole Dominion of Canada 107.7 per cent. With the recent addition of the District of Patricia, containing 157,400 square miles, Ontario now has an area of 407,262 square miles. The geology of the District of Patricia presents about the same features as does that of the region hitherto known as Northern Ontario, being underlain mainly with rocks of the pre-Cambrian age. Public attention has been directed to Ontario as a mining province for many years past, and ample capital has been provided, mainly by private effort, for its intelligent exploration and prospecting. Nowhere in Canada are there so many or more intelligent and resourceful prospectors, so that the great area of hitherto unprospected country is receiving capable examination. It seems certain, therefore, that Ontario must, in these circumstances, hold her position as the foremost mining province for many years to come.

"In Alberta, the development of the coal industry in recent years has been astonishingly rapid. The progress this year is more than maintained. The future may perhaps be better appreciated when we learn that Mr. D. B. Dowling of the Geological Survey estimates that the mineable coal of the Central Plains and the Eastern Rocky Mountains, explored with some accuracy, amounts to $130,400,000,000 tons.*

"In British Columbia the extension of the railway systems and the building of new lines has rendered a large additional territory accessible to the prospector. This extension of readily explorable country is sure to have a stimulating effect on the mineral industry of the province. The discovery and preliminary development of the Groundhog Coal Basin already presages a large and valuable new anthracite field, while the opening up of the Granby Copper Company's property on Observatory Inlet will be followed shortly by the erection of a smelter at that place.

"In connection with the progress of our industry, may I add before closing, a few words of appreciation of the work of

*Bulletin Canadian Mining Institute, June 1911, pp. 87-107.

the Geological Survey of Canada. At our last annual meeting in Toronto there was a rather regrettable occurrence when a mining engineer of repute questioned the value of much of the geological work carried on in Canada. The incident only tended to accentuate, if there was need, the close interdependence of geology and mining. Some universities, notably Wisconsin, with a full cognizance of such a close relationship, have so fashioned a course that they train mining engineers, who are at the same time very capable geologists. I am happy to be able to say that the Canadian Mining Institute of late years has recognized the disinterestedness of geologists, for I am the third geologist in succession to be elected to the Presidency by the mining men of Canada. The Geological Survey is doing, and has done, a vast amount of work, which has been of the greatest assistance to mining. Its present director, Mr. R. W. Brock, is a man who has devoted many years of his life to the study and practice of geology in its relation to mining. His presence here with a number of the staff of the Geological Survey is evidence of the continued and great interest of geologists in mining. In British Columbia, the Geological Survey are spending more money and doing more work than in all the rest of Canada. Mr. Brock will doubtless explain to you that British Columbia is the best training ground in the Dominion, since geology is here seen in its three dimensions. The principles and examples of structure, so well illustrated in the developments of the majestic mountains, are thus more readily understood in British Columbia and Western Alberta than, perhaps, elsewhere in Canada. All credit, therefore, to the Geological Survey, which for many years has done such zealous, disinterested and capable work in assisting the mining industry of Canada. It has sometimes been misunderstood or misrepresented, but withal it is held in high esteem by the mining community.

"I may also appropriately refer here to the International Geological Congress, which meets in Canada in August of next year (1913). Part of the duty that brought me to the West this year was that I might assist in the arrangement of a Western excursion on the main line of the Canadian Pacific Railway. The visiting geologists will come from all parts of the world

where geology is taught and practiced. It will perhaps be the greatest opportunity for legitimate advertising of the natural resources of Canada that has ever been afforded. We are using every endeavour to make the sessions in Toronto, as well as the excursions before and after the sessions, unqualifiedly successful. Later on I will ask Mr. Brock, who is the General Secretary, to go more fully into the details, as we wish to enlist the sympathy and co-operation of all the mining men as well as of of the geologists throughout Canada, in the arrangements.

"In conclusion, our presence at this meeting, at the busiest season of the year, is a sufficient evidence of our conviction of the value of the Institute to the mining profession. The Canadian Mining Institute is a thoroughly national and representative body. In the West the progress of the Institute is very gratifying, while in Ontario, Quebec and Nova Scotia we have a very large and enthusiastic membership. The discussions at the meetings of the various branches are very instructive, at the same time affording an opportunity for the interchange of friendly greetings and courtesies. I would again express myself as being much gratified that I have the honour of presiding at this, the first semi-annual meeting in British Columbia. I had hoped for a larger gathering, but what it has lacked in numbers has been more than compensated by the evident interest in the proceedings of those present."

General Business.

Among matters brought forward for discussion were the proposed amendments to Sections 33, 34 and 35 of the By-laws. These amendments, originally introduced by Mr. W. F. Ferrier at the last annual meeting in Toronto, were there submitted for consideration to a thoroughly representative committee and, with minor changes endorsed by them, final action by the Institute being, however, deferred for another year. The Secretary explained the reasons, which, in the opinion of many members, rendered the proposed changes desirable, adding that advantage had been taken of the present occasion to afford Western members the opportunity to express themselves on the subject should they desire to do so.

FEDERAL DEPARTMENT OF MINES.

In calling attention to the fact that under present arrangements the mining industry was not adequately represented in the Federal Cabinet, the Secretary briefly surveyed the conditions that led to the creation of a Department of Mines at Ottawa. The establishment of this department was almost entirely due to the representations of the Institute, whose efforts, however, were only partially successful until some five years ago, when an Act was finally passed establishing a Department of Mines. It was placed under the ministerial direction of Mr. Templeman, a gentleman whose long residence in the West had given him a considerable knowledge of the requirements of the mining industry. Unfortunately, as it has turned out (for it has created a precedent), Mr. Templeman held the dual office of Minister of Mines and Minister of Inland Revenue. The administrative duties appertaining to the latter department are relatively light, and Mr. Templeman, during the time he was in office, was occupied mainly in directing and administrating the affairs of the Mines Department. With the change of Government, a gentleman not possessing Mr. Templeman's special qualifications, received the portfolios of Inland Revenue and of Mines. Later a change was made, the Mines' Department being transferred to the Department of the Interior, whose Minister is already overburdened and whose duties are multifarious. There is no branch of the Government service in greater need of organization and ministerial control than the Department of Mines, while under the guidance of a responsible Minister the efficiency of the department could unquestionably be greatly increased. In reference to Mr. Templeman's remark that the Government may not consider it politic or expedient to make any further additions to the Cabinet, the suggestion has been offered that it would not only be possible, but advantageous, to combine certain of the ministerial offices. For example, Inland Revenue could properly be included with Trade and Commerce, while a Department of Natural Resources, embracing mining, forestry, water powers, etc., would serve a most excellent purpose.

Mr. Jacobs considered that every effort should be made to secure for the mining industry that representation and consideration its importance warranted.

Mr. L. O. Armstrong remarked that he was greatly interested in the suggestion that there should be a Dominion Department of Natural Resources. The Canadian Pacific Railway Company had established such a department with the best possible results.

After some further discussion, in which the President and Mr. W. J. Sutton participated, the following resolution, moved by the latter gentleman and seconded by Mr. Charles Graham, was carried unanimously:

"WHEREAS the mining industry of Canada is a chief source of our national wealth and prosperity; and whereas it is eminently desirable that this industry should be adequately represented in the Council of the Dominion Government and in Parliament; and whereas the administration of the Department of Mines is at present directed by the Minister of the Interior, whose departmental duties are acknowledged to be already exceptionally onerous;

"BE IT THEREFORE RESOLVED, that we, the Canadian Mining Institute, in general meeting asesmbled, respectfully petition the Government of Canada to favourably consider the advisability of creating a Minister of Mines for the Dominion."

WEDNESDAY AFTERNOON SESSION.

In the afternoon, Dr. Barlow delivered an interesting lecture, illustrated with lantern slides, on the geology and mineral resources of Northern Quebec and Ontario. The discussion that followed covered a wide range, and occupied the greater part of the session. In reply to one enquiry, Dr. Barlow stated that during 1911 the Cobalt District produced 14 per cent. of the world's supply of silver, and thus was responsible for placing Canada in the third position among the silver-producing countries of the globe. The total output of silver from the camp to the close of 1911 represented $64,918,752, of which nearly one-half had been distributed in the form of dividends. Of the thirty mines regularly productive in 1911, eighteen had paid dividends. In respect of Porcupine, he was given to under-

stand that the year's production, dating from the commencement of crushing operations, would not fall short of a valuation of two million dollars.

The afternoon's programme concluded with an account given by Mr. R. W. Brock of the arrangements that had been made in connection with the visit to Canada next year of geologists attending the International Congress, of which Mr. Brock is the General Secretary. He also invited the co-operation of Western members to ensure the success of excursions to Western Canada.

EVENING SESSION.

At this session a paper was presented by Mr. E. Jacobs, dealing generally with the copper mining industry of British Columbia. Some excellent slides were thrown on the screen, illustrating methods of mining in the several districts, and of the principal metallurgical works. The industry is in a more flourishing condition than at any previous time, and the author directed attention in particular to the important new developments at Granby Bay, Observatory Inlet, and remarked on the satisfactory progress now being made in the development of the Britannia Mine, at Howe Sound.

THURSDAY MORNING SESSION.

The first paper presented was one by Mr. F. Napier Denison, dealing with the subject of the relation of earthquakes to colliery explosions. In the course of his remarks he stated he was firmly convinced that a direct connection could be established between slow earth movements and colliery disasters. In fact from the records that had been kept this connection appeared to have been proved. In the case of colliery disasters in Great Britain, covering a definite period, it was demonstrated that 67 per cent. of the disasters occurred within twenty-four hours of the occurrence of earthquakes. In the United States the percentage was found to represent 46 per cent.

Mr. Denison then exhibited the seismograph, designed by himself, for recording earth movements in mines, and demonstrated its operation. One such instrument has been placed underground, at a depth of 979 feet, and another at the surface in one of the mines of the Western Fuel Company at Nanaimo.

Mr. Shallcross remarked that Mr. Denison's investigations had created much attentions, and the Victoria Board of Trade considered the matter to be of sufficient importance to justify them in urging the Dominion Government to provide the funds necessary to further the work in question.

Mr. Sutton stated that from a practical mining standpoint the investigations were of value. Vancouver Island is in the seismic zone of the Pacific Coast, and it is well known that earth movements have been frequent here in recent geologic times. Hence the opportunities were particularly favourable for the conduct of investigations of this character. "We have," he added, "extensive coal mines on the island, and it certainly appears that there is a sympathetic relationship between earth strains and the outbursts of large volumes of gas. For this reason I consider it highly important that the Government should establish a well-equipped seismological station on this coast."

Mr. Mortimer-Lamb expressed the opinion that Mr. Denison might advantageously seek the co-operation of the Department of Mines at Ottawa in establishing the correctness of his theory. If, he said, Mr. Denison was able to conclusively demonstrate that there was a definite relationship between earth movements and explosions, and if, as has been advanced, there are certain periods or cycles when earth movements are known to be more frequent than at others, it would appear that these investigations might be turned to very practical account.

Mr. Denison stated that he welcomed the proposal, and a resolution was accordingly adopted by which the Secretary was requested to bring the matter to the attention of the Director of Mines, with the suggestion that, if practicable, seismographs be placed in coal mines throughout Canada, and that the department ascertain and determine in what further directions research may be carried, having particular regard to the practical application of Mr. Denison's theory.

Mr. D. B. Dowling then read a paper, "Fuel Problems of the Pacific," originally presented by Mr. H. Foster Bain at the annual meeting of the Institute. This was productive of an interesting discussion, elsewhere reported in this volume.

THE DUTY ON RESCUE APPARATUS.

Mr. Thomas Graham suggested that the Institute should apply to the Dominion Government for the removal of the duty on rescue apparatus for use in mines. The Western Branch some time ago had made an application to the authorities in this respect, and had been assured that action would be taken accordingly; but nothing had been done. Meanwhile coal mining companies are importing apparatus, and, although the duty is always refunded on application, the companies are subjected to the annoyance and trouble of an official correspondence, to an extent often not commensurate with the amount of money envolved.

The Secretary stated that during the past two years the Council had made repeated representations to the Government to this effect. An application was made to the Minister of Customs last spring, and resulted in a lengthy correspondence. The Minister was informed that life-saving apparatus for use other than in mines was admitted duty free; that mining machinery not manufactured in Canada was also on the free list, and a ruling was asked that mine rescue apparatus be placed in one of these categories. The department had replied that in order to comply with the request it would be necessary to pass special legislation, but advised that the attention of the Tariff Commission be directed to the anomaly. The Commission has not yet been appointed, but the Council had no intention of allowing the matter to drop.

On motion of Mr. Jacobs, votes of thanks were then tendered to the Victoria Board of Trade, for having placed their rooms at the disposal of the Institute, and to the local press for courtesies and attention. The Secretary also took the opportunity of speaking appreciatively of Mr. Jacobs' services to the Institute, and acknowledged the assistance rendered by that gentleman on the present occasion.

The meeting then adjourned.

In the evening, the Institute and its Western Branch, acting jointly as hosts, entertained the Hon. Wm. Templeman and Mr. J. J. Shallcross at a dinner served at the Empress Hotel.

Group of members and others at the Victoria, B.C., semi-annual meeting, September, 1912.

Frank meeting, September, 1912.

FRANK MEETING.

The adjourned meeting was held in the Sanitarium Hotel, at Frank, on September 30th. In addition to the officers of the Institute there were present: Messrs. Lewis Stockett, Calgary; D. G. Wilson, Hosmer; John Shanks, Coal Creek, B.C.; Leonard C. Stevens, Burmis; Andrew A. Millar, Blairmore; R. W. Coulthard, Calgary; Evan Evans, Fernie, B.C.; E. Gheur, Toronto; J. Menard, Blairmore; S. A. Jones, Lethbridge; S. Shone, Bellevue; Robt. Hamilton, Redcliff; A. N. Scott, Calgary; O. E. S. Whiteside, Coleman; W. F. McNeill, Calgary; A. Rotteleur, Frank; J. Bilteryst, Blairmore; W. A. Davidson, Coleman; R. H. Morris, Pocahontas; W. R. Wilson, Fernie; R. Livingstone, Lethbridge; John Brown, Hillcrest; J. D. Thomas, Passburg; W. L. Hamilton, Medicine Hat; W. Hutchinson, Hillcrest; D. A. McAulay, Coleman; Raoul Green, Blairmore; L. P. Robert, Blairmore; and John T. Stirling, Edmonton.

The morning session was devoted almost exclusively to general business. As in Victoria, the proposed amendments to the by-laws were explained and discussed, and resolutions were adopted similarly worded to those passed at the Victoria meeting, urging the Dominion Government to appoint a Minister of Mines for Canada and provide for the free entry of mine rescue apparatus. The organization of a local branch of the Institute for Southern Alberta was also considered, the concensus of opinion being, however, that the branch should be representative of the coal mining industry of both Southern Alberta and Southeastern British Columbia. It was consequently decided to organize with this intention, and the branch will be known as the Rocky Mountain Branch of the Institute. Mr. W. R. Wilson, general manager of the Crow's Nest Pass Coal Company, by a unanimous vote, was elected Chairman; Mr. J. T. Stirling, Provincial Inspector of Mines of Edmonton, Secretary; while Mr. O. E. S. Whiteside, of Coleman; Mr. W. F. McNeill, Mr. R. W. Coulthard, and Mr. Lewis Stockett, of Calgary, and Mr. Robert Livingstone, of Lethbridge, were elected to serve with the Chairman and Secretary as an Executive Committee. In the course of the morning Mr. Mortimer-Lamb gave

a brief history of the Institute, and referred to its activities and aims.

AFTERNOON SESSION.

Four papers were presented and discussed at the afternoon session, the first by Mr. W. D. L. Hardie (read by Mr. Coulthard) on the subject of "Engineers' Reports on Mines," created much interest. The author emphasized the point that the value of any report was entirely dependent on the application of scientific methods of valuation. He advocated that in making valuations, both "remunerative and accumulative interest on the investment should be taken into consideration," and quoted freely from King's Theory of Finance in support of his contention. In the discussion that followed it was urged that engineers should make a practice of publicly protesting on each and every occasion when their views were misrepresented in consequence of the very common plan adopted by promoters of merely publishing extracts, without the context, of a report. A case was cited where an actually adverse report had been successfully employed by this means to extract money from the public.

Another interesting paper, productive of much discussion, was that by Mr. W. F. McNeill on "Provincial Mining Legislation," in which such matters as Workmen's Compensation and the Eight-Hour Law were considered. The present law in Alberta in respect to the former was criticized, but it was decided to discuss the issues raised at greater length at the meeting of the Branch to be held in Lethbridge in November.

Mr. R. H. Morris, general manager of the Jasper Park Collieries, gave an interesting account of the development and equipment of these mines. As Mr. Whiteside remarked, operators in the southern fields of the province are quite ignorant of the progress of coal mining in northern country, and he and others expressed astonishment at learning that so much had been accomplished in the very limited time stated.

Before the close of the proceedings, a vote of thanks, on motion of Mr. Whiteside, was tendered the President and Secretary, "who had travelled so great a distance and had gone to so much pains to provide for a meeting of the Institute in Alberta:

and which had resulted in the organization of a branch which it was hoped and believed would serve a most useful purpose."

The Secretary in reply said that as a paid official he was in no sense deserving of or entitled to special thanks, but in the case of men such as the President, who ungrudgingly sacrificed time and money to the service of the Institute, it was right and fitting they should be accorded full recognition and gratitude. The high standing and usefulness of the Institute was entirely due to the disinterested zeal and the unselfish devotion of individual members, not exclusively restricted to those who had or were holding office. The success of the present meeting was in a very large measure attributable to the efforts of the convenor, Mr. Stirling, and to the co-operation of the members of the local committee, and he begged to move a vote of thanks to these gentlemen. Dr. Barlow said that, although chairman of the meeting, he would be glad to be permitted to second this motion.

BRANCH MEETINGS.

WESTERN BRANCH.

The twelfth general meeting of this Branch was held in Vancouver, B.C., on February 15th and 16th, 1912. Mr. Robert R. Hedley, Chairman of the Branch, presided. Among the papers read and discussed were the following: "The Coal Fields of the United States," by E. W. Parker; "Roslyn Coal Field, in Kittitas County, Washington," by Professor Daniels; "A Brief Description of the Electrolytic Lead Refining Plant of the Consolidated Mining and Smelting Company, Limited, at Trail, B.C.," by J. Miller; "Operating Costs at a Small Free Milling Gold Mine," by A. H. Gracey; "Mining and Metallurgy on the Pacific Coast," by Professor Milnor Roberts; "Some Work of the United States Bureau of Mines—Field Investigation, Mine Safety, and First Aid," by H. M. Wolfin; "The Groundhog Coal Basin," by G. S. Malloch; and "Notes on the Progress of Development Work on Coal Areas in Alberta and Saskatchewan," by D. B. Dowling.

COBALT BRANCH.

Two meetings of this Branch have been held during the year, the first on January 26th, and the second on May 1st. At the January meeting papers were presented by C. H. Hair, M.D., and by G. H. Schmidt, M.D., dealing respectively with "Sanitation in Mining Camps," and "Miners' Pythisis." At the May meeting a paper was presented by Mr. George R. Mickle, Mine Assessor for the Government of Ontario, entitled "The Probable Number of Producing Veins in the Cobalt District." The following gentlemen were elected to serve as a local executive: Chairman, Mr. Norman R. Fisher; Secretary-Treasurer, Mr. Arthur A. Cole; Committee, Messrs. A. J. Hewitt, Carl Reinhardt, and J. I. MacVichie.

EASTERN TOWNSHIPS BRANCH.

A largely attended meeting of this Branch was held in Sherbrooke on October 2nd. The Chairman, Mr. John J. Penhale, presided. Papers were presented by Mr. J. M. Forbes,

Mr. W. R. Leventritt, Mr. W. J. Woolsey and Mr. Andrew Sangster.

OTHER BRANCHES.

Numerous meetings have been held during the year under the auspices of the Porcupine, Toronto and Montreal Branches respectively.

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PAPERS AND DISCUSSIONS

THE ELECTRIC SMELTING OF ZINC ORE.

By W. R. Ingalls, New York, U.S.A.

(*Annual Meeting, Toronto,* 1912.)

The electric smelting of zinc ore during recent years has engaged much attention. It is not a new idea. The Cowles brothers tried it in 1885, which was the first attempt (so far as I am aware), and since then numerous experimenters have undertaken it. It is not my intention in this paper to trace their work, or go further into the history of the subject. It is sufficient for my present purpose to mention that C. P. G. De Laval was the first to erect an electric zinc-smelting furnace on a commercial scale, this having been done in Scandinavia in 1901. Works were later erected at Sarpsborg, in Norway, and at Trollhättan, in Sweden. I do not know precisely the dates of their erection, but they were in operation as early as 1905. It was attempted at first to smelt ore, but for a long time this was not commercially successful, the product being chiefly zinc powder, which had to be subjected to resmelting, giving an impure spelter, which had to be refined. The works were continued in operation in a more or less irregular way and spelter from them came on the market, but this was the product of smelting dross, scrap and other secondary products rather than ore. Some progress in ore smelting was made, however, and during 1911 a considerable quantity of ore was smelted by a method, to which I shall refer subsequently.

There is much misconception respecting both the ordinary art of zinc smelting, and the possibilities of electric smelting. In the first place, the ordinary art of zinc smelting is not extraordinarily backward, in spite of the small retorts to which we are limited; and although we are attracted by the possibility of conducting the distillation in a relatively large apparatus,

electrically heated, I am not yet by any means prepared to say that electric smelting will offer any advantage over existing methods, even if the difficulties that are now in view can be overcome. In the second place, electric smelting is not to be expected to accomplish the establishment of any radically new metallurgical principle. If there be any dreams of an electric furnace analogous to the blast furnace, in which run-of-mine ore may be charged roughly and from which spelter, lead and perhaps also copper matte, may be obtained concurrently, I fear that there will be no realization of them.

Carbon Reduction and Iron Decomposition.—Whatever be done in electric smelting is generally expected to be based on the reduction of zinc oxide (or its compounds) by carbon (and carbon monoxide); but the decomposition of zinc sulphide by iron has also been contemplated. The former is the basis of ordinary practice. The latter has been exploited in the electric smelting of Coté-Pierron and of Imbert-Thomson-Fitzgerald. While the decomposition of zinc sulphide by iron has not found application in ordinary furnace work, it has been repeatedly suggested. Indeed, the Imbert process was originally such a suggestion, the use of an electric furnace for its execution being an afterthought. The Coté-Pierron process was tried experimentally at Lyon, France, in 1906, and in 1907 at Arudy, in the Basses-Pyrenees, and was ephemerally the subject of many articles in the technical press, but lately it has not been mentioned, and I am inclined to think that the results were not satisfactory. The Imbert-Thomson-Fitzgerald furnace has been in trial at Hohenlohehütte, Upper Silesia, during the last two years. No authoritative reports of the results recently obtained there have been made public. The imperfect news that seeps through professional and commercial channels is conflicting. I shall not in this paper discuss either the Coté-Pierron or the Imbert-Thomson-Fitzgerald proposals, but shall confine myself to a consideration of the reduction of zinc oxide by carbon. In this discussion I shall draw upon general metallurgical experience, upon the information obtained in experimental electric zinc-smelting at McGill University, and upon the authentic reports of work that has been done elsewhere.

The reduction of zinc oxide is an endothermic process, i.e., heat must be supplied to it. This may be done either by the external heating of the retort containing the charge by the combustion of coal, or by internal heating by means of the electric current. The theoretical advantage of the latter rests in the possibility of developing the heat in the midst of the charge, i.e., in the heart of the place where the work is to be done, a condition that does not exist in ordinary external heating. The electric furnace may be of two types, namely, the arc furnace and the resistance furnace. To draw a familiar analogy, the arc furnace is exemplified by the ordinary arc lamp used for illumination; the resistance furnace by the ordinary incandescent lamp. Another type of furnace, namely, the induction furnace, will not here be taken into consideration.*

Types of Furnaces.—The original De Laval furnace was a simple arc furnace, in which the heat of an electric arc, formed between electrodes projecting horizontally into the furnace, acted upon the charge of ore lying under it. Among the various types of resistance furnace we may have that in which the current passes through a resistor of carbon (as in the Imbert-Thomson-Fitzgerald), or that in which the electrodes dip into the charge to be smelted, or into a bath of slag which serves as the resistor. It will be unnecessary for the present consideration to go any further into the subject of the types and design of furnaces. It is the fundamental metallurgical principles upon which it is still most important to centre attention. In the present status of the art of electric zinc-ore smelting, the functions of the electrician are subordinate to those of the metallurgist.

In the earliest attempts to smelt zinc ore electrically, the conception was of an apparatus similar to an ordinary retort, but electrically heated. In some of our early experiments at McGill University, we used furnaces of analogous character. The rate of reduction in these furnaces was about on a parity with the rate in the ordinary retort, temperatures being equal, which was, of course, what was to be expected. These experiments, made primarily for another purpose, confirmed the idea

*An induction furnace has been proposed by G. Gin, but it has not been tried, so far as I am aware.

that if electric smelting were to offer any advantage, it must be conducted continuously. Here is introduced a departure from the conditions of ordinary smelting, which is an intermittent operation, conducted in two stages, the first comprising the expulsion of aqueous vapor, and the decomposition of hydrocarbons and carbonates; and the second being that of the reduction of the metallic oxides. If zinc smelting is to be done continuously, it seems that the operation must be confined to the second stage, which implies that the things that ordinarily happen in the first stage must be caused to take place by a previous preheating. With such a preheating the actions in the furnace become essentially the same, but there are certain important differences.

Differences from Ordinary Practice.—One of these differences pertains to the carbonaceous reduction material that is mixed with the ore. It has been shown by Boudouard that the permissible limit of carbon dioxide in the gas of the zinc retort is very low; varying with the temperature, but still very low at the very high temperature of 1,500 deg. C., a temperature that is not attained in practice. When the permissible limit is exceeded, carbon dioxide acts oxidizingly upon the zinc, and coating the condensing globules of the latter prevents coalescence and forms powder.

The gas issuing from the zinc retort of practice is within the permissible limit of carbon dioxide, or nearly within it, and the zinc is condensed chiefly as molten metal. Conversely, all attempts to smelt zinc ore in the blast furnace have resulted only in the production of powder because of inability to control the percentage of carbon dioxide. Small quantities of molten zinc have been occasionally found in the blast furnace, undoubtedly due to the accidental occurrence of favourable conditions.

The uniformly favourable conditions of the ordinary zinc retort are due to its small size, its confined character, and the presence of an immense excess of carbon in the charge. Carbon dioxide, resulting from the reduction of zinc oxide, and from other reactions, is immediately exposed to the great surplus of finely divided, intimately admixed, incandescent carbon, and is reduced by it to monoxide.

Continuous charging implies discharging of the residue without interrupting the smelting operation. This in turn implies the discharging of the residue as a slag that will run. Both conditions imply the absence of any great excess of carbon, which cannot be slagged and cannot be permitted to accumulate in the furnace. In this important particular, the internally heated, continuously operated retort or furnace differs materially from the externally heated, intermittently operated retort.

Carbon Dioxide.—In our experimental work at McGill University, we have commonly found high percentages of carbon dioxide in the gases from the furnace, much higher than exist in the gases from the ordinary retort. Besides this difference we have observed the presence of considerable quantities of carbon and ore-dust in the condensers, indicating another variation from the conditions of the ordinary retort. In the continuous feeding of the charge into the electric furnace, there is naturally stirred up some dust which may be, and probably is, carried out into the condenser by the relatively strong outrush of gas and vapor; the latter may indeed entrain some dust from the surface of the charge in the furnace. There may be some other physical disturbances.

The effect of the carbon dioxide in the gas has been recognized by Coté & Pierron, by Johnson, and by other investigators who have caused the gas and vapor from the retort to pass through a column of incandescent carbon, the purpose of which is to act as a secondary reducer. This is believed to be, at least, ameliorative.

Except for the metallurgical differences that have been previously pointed out herein, the reactions and condition in the internally heated retort are essentially the same, providing that the charge introduced into the former be preheated to a degree corresponding to the preheating that takes place in the first stage of the intermittent process. The gradually introduced charge, with its interstitial air, should not involve any new conditions, except those previously noted, inasmuch as the gas inside of the furnace displaces the interstitial air before the charge enters into the smelting chamber. The reduction of lead and iron, developing carbon dioxide, and the multiplicity of com-

plex side-reactions, take place in one kind of retort as well as in the other.

There is no positive evidence that the electric current passing through a furnace plays any metallurgical part other than thermic. Harbord reports no observed difference between the actions of the arc furnaces at Sarpsborg and the resistance furnaces at Trollhättan, except in the efficiency of the energy supplied. At McGill University we observed arcking in the furnace when a resistor of fragments of carbon was used; and this arcking was followed by disturbance in the furnace that we have been unable to explain; but there was no such occurrence in a furnace with a continuous resistor of carbon, in which furnace the reduction of zinc oxide appeared to take place regularly and normally. This particular furnace was provided with a peep hole (closed by mica), through which the process of distillation could be observed. The resistor was vertical in position, the charge surrounding it. The distillation proceeded most actively around the resistor, the heating element, the charge coming down toward this as the zinc was expelled, and the interior of the furnace maintaining an even incandescence.

Speed of Reduction.—Our attempts at McGill University to reduce zinc oxide in an intermittently charged, electrically heated retort, resulted in so slow a reduction that the prospect of advantage seemed to be insignificant. I refer to a retort in which the charge was introduced in the usual manner at the beginning of the operation, the residue to be discharged as an unfused ash. There was, of course, a possibility of converting this from an intermittent to a continuous operation, but, as I have already stated, the slowness of the reduction under these conditions dispelled any such idea. When we changed to the scheme of starting the furnace with a bath of slag, continuously introducing the charge upon this bath, we found immediately that the reduction became relatively rapid. I am unable to offer an adequate explanation of the improvement in this respect. I can but state that a retort of small proportions smelts a surprisingly large quantity of charge by comparison with the retort of ordinary practice at an equivalent temperature. With a furnace of which the laboratory was a plumbago crucible 12 inches

in diameter, we have been able to smelt 10 lb. of ore per hour. With a furnace 18x18 inches in horizontal section, we smelted 737 lb. in 23 hours. We have learned consequently that the claims of extraordinary capacity of electric zinc smelting furnaces of comparatively small size are well founded.

Bearing in mind the main difference between the conditions of ordinary and electric zinc smelting, we may pass on to a consideration of similarities. There is no reason to believe that the reduction of the metallic oxides, the reactions between metals, oxides, sulphides and sulphates, the scorification of oxides, and, in short, the multiplicity of complex reactions that we believe to take place in the externally heated retort, will be any different in the internally heated, the nature of the charge and the temperature remaining the same.

The Matter of Temperature.—With respect to the matter of temperature, that of the electric furnace may be anything that it is pleased to make it, within the limitations of the material whereof the furnace may be constructed. In the ordinary practice of zinc smelting, the tendency in Europe during recent years has been to drive the furnace harder and harder. A furnace temperature of 1,400 degrees C. was once thought to be high, but now 1,500 degrees C. and upward is reported. Such high temperatures imply, of course, the necessity for much more substantial furnace construction and a high class of refractory material. Naturally, the average life of the retorts is reduced. The actual smelting temperature, i.e., the temperature inside of the retorts, is about 100 to 200 degrees less than the furnace temperature. In this particular the electric furnace has the advantage that the full temperature of the furnace is realized in just the place where the smelting is to be done.

The amount of zinc remaining in the residuum, whether the latter be an ash (loose or clinkered) or a slag, depends primarily upon the temperature of the smelting and the fluxing of the ore. Conditions favourable to low zinc retention are high temperature and highly calcareous slag. It is possible to discharge from the electric furnace a slag containing less than 1% of zinc. We have made such slags at McGill University, and other experimenters also have done so. The ability to do that does not,

however, imply either commercial feasibility or advisability. It may be impossible to maintain a furnace in continuous operation under the conditions necessitated by the production of such a slag. This matter has not yet been worked out. The slag made at Trollhättan, during Mr. Harbord's test, was high in zinc. We do not as yet know much respecting the shape that the smelting chamber of an electric furnace will naturally assume, the formation of refractory accretions on the walls, the deposition of sows of metallic iron (that doubtless will be produced in the same way as in the ordinary retort), and the difficulties that are likely to occur in continuous operation from these things.

Smelting at Trollhättan.—The operations at Trollhättan and at Sarpsborg were the subject of a report by F. W. Harbord in 1911, which is the only recent source of technical information respecting them. Mr. Harbord's report was made privately for commercial purposes and did not go fully into the metallurgy of his subject. Mr. Harbord conducted a test at Trollhättan, during which 537 metric tons of ore were smelted, the test extending through 27½ days. This is the longest continuous run on a large scale that has been reported. The ore was essentially a zinc-lead ore, rather than a zinc ore, and was high in silver, containing 36% zinc, 24% lead and 30 ounces silver per ton. In making deductions from the experience in smelting this ore, we must hesitate in applying them too freely to the cases of what are more distinctly zinc ores. Mr. Harbord extracted 64% of zinc, 74% of lead and 46% of the silver as metals, which percentages would be slightly increased by further treatment of certain incidental products, but even so the metal recovery would still be relatively low. A summary of Mr. Harbord's report is to be found in the *Engineering and Mining Journal* of February 10th, 1912. Briefly, the furnaces were of the resistance type, having one large vertical electrode passing through the roof, the other electrode being a carbon block bedded in the bottom of the furnace. Each furnace smelted about 2,800 kg. of ore per 24 hours. The product was partly metal and partly blue powder and oxide, con-

taining about 54% of zinc and 20% of lead. This powder is mixed with fresh ore and recharged, when a larger percentage of the metal volatilized is recovered as metal. The first operation of smelting ore alone is to be regarded mainly as a concentrating process for the production of a rich oxide. The regular charge was 100 kg. of roasted ore, 200 kg. of powder, 25 kg. of coke dust and 5 kg. of lime. Thus for every ton of ore smelted, two tons of powder had to be resmelted; indeed rather more than that, there having been an accumulation of powder during the run.

Recovery of Lead.—In the ordinary retort the lead content of the ore is reduced and is partly volatilized, condensing with the zinc, which it contaminates; and partly remains as metal in the residuum, from which it is recovered by smelting the latter, or by jigging and smelting the concentrate. The percentage of lead volatilized increases with the temperature. In the electric furnace lead behaves in the same way, but in fusing the residuum into a slag, the lead is given an opportunity to separate and thus may be tapped separately, which in so far is an advantage. On the other hand, the desirability or necessity of smelting at a high temperature leads to the collection of a leady spelter, which must undergo a subsequent refining, and the experience at Trollhättan has indicated difficulties in the furnace construction because of the lead.

I am not greatly attracted by the possibility of smelting for lead and zinc in a single operation, much less by aiming also to make a matte (although that may be inevitable), which adds to the difficulties, nor do I see any good reason to head in that direction. In most kinds of mixed sulphide ores the galena is easily separated to a fair degree by gravity concentration, and no loss need be experienced in such a separation, inasmuch as the galena and the blende-pyrites may be easily collected in filter bins. It should be the policy first to subject the ore to this cheap process, very likely cutting out a portion of the gangue sufficiently clean to be discarded, and pass the galena on to ordinary lead smelting, also a relatively cheap process, rather than to deliver all of the ore to the zinc-smelting process, which must

inevitably be relatively dear, whether it be the ordinary one or the electrothermic.*

There will be, of course, from such a treatment a percentage of lead in the blende-pyrites, and being there it will be desirable to extract it, but it is troublesome both in the roasting and in the smelting, and I conceive that the electric smelter, like the ordinary smelter, will rather have a zinc ore without lead than with it, unless it can be obtained on terms that compensate for the disadvantages. It may be accepted, however, that the electric furnace will probably obtain a higher extraction of the lead and at less cost than is possible in the ordinary method of smelting, and there are some ores wherein the galena and blende are so intimately mixed that mechanical separation is impossible, which may be treated more advantageously in the electric furnace than in any other way. I do not by any means regard this as a step in metallurgy that has yet been accomplished, but it is a possibility. The work at Trollhättan has been in this direction.

Condensation.—It has been assumed by some investigators that the difficulty of condensing the vapor resulting from the reduction of zinc oxide, lies chiefly in the condensing apparatus. It may be taken for granted that the condenser connected with an electric zinc-smelting furnace, required to deal with a relatively large quantity of vapor and operating under some conditions different from those existing in connection with the ordinary furnace, must be of dimensions and design conforming to the new conditions.† It has been found possible to condense the zinc satisfactorily as spelter from the electric furnace treating zinc powder and galvanizers' dross. This has been done at Trollhättan, where, in the refining of crude zinc, but 9.8% of

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*The great progress in the treatment of mixed sulphide ores has been in the development of improved processes of mechanical concentration. See my paper on this subject in Proceedings of the Canadian Mining Institute, 1911.

†The condenser of the electric furnace receives no radiant heat from the front of the furnace nor from the glowing charge in the retort. On the other hand, the condensation of a large amount of zinc vapor liberates a relatively large amount of latent heat. The balance between these conditions has by no means been worked out. We find some experimenters having artificially to cool the condenser and others to heat it.

powder has been collected. In refining 111,794 kg. of leady spelter, Mr. Harbord obtained only 11,209 kg. of powder. Charles A. Weeks reported, in *Metallurgical and Chemical Engineering* of July, 1911, that in the refining of zinc dross in an electric arc furnace, during a run of 36 hours, no powder was made. In a private communication, Mr. Weeks informed me that this furnace was built and operated in the works of the General Electric Co., at Schenectady, N.Y. Accepting the foregoing evidence, which is confirmed by experience at McGill University, the reason for the production of blue powder is to be sought not in the condenser proper, but in the character of the gas and vapor delivered to the condenser; in other words, to the conditions that exist and the reactions that take place inside of the furnace itself. It has been found that when metallic zinc is simply distilled, there is no great difficulty in condensing the vapor in a liquid form, but when the vapor originates from the reduction of zinc oxide, there is difficulty.

Blue Powder.—Nearly all experimenters in ore smelting by the reduction of zinc oxide by carbon have been baffled in the attempt to condense a commercial proportion of the zinc as molten metal. We have encountered this difficulty in our experimental work at McGill University, and have not yet been able to master it. The reason why zinc vapor from the electric furnace should condense in this way has not yet been satisfactorily explained. It may pertain to the differences between the conditions of ordinary smelting and electric smelting that I have already mentioned; it may pertain also to other conditions. I shall not advance hypotheses respecting this; I shall limit myself to the mere statement of the fact.

At the present time the matter of reducing and distilling the zinc and condensing the latter chiefly as spelter and blue powder, is the crucial point of electric zinc-ore smelting. Until that has been accomplished, I can see no future for the process, except under special conditions of extraordinarily cheap power, peculiar kinds of ores, etc. On the basis of ore alone, the consumption of power at Trollhättan was 2,078 kw.-hr. per 1,000 kg. of ore, but for every ton of ore smelted about two tons of powder had to be resmelted. The smelting of

1,000 kg. of ordinary zinc ore is reckoned to require from 900 to 1,000 calories of heat, which is equivalent to 1,047 to 1,163 kw.-hr. of electric energy, these figures representing the cases of ordinary ores containing 25 to 50% zinc. In one run at McGill University, lasting 24 hours, with a resistance furnace, 18 x 18 inches, Dr. Stansfield determined the power consumption per 2,000 lb. of ore smelted as 1,610 kw.-hr. (about 1,771 per 1,000 kg.). It has been claimed that it is possible to smelt 2,000 lb. of zinc ore with 1,000 kw.-hr. While it is doubtful whether such a result has yet been actually realized by anyone, the claim is plausible with respect to certain kinds of ore, although even then it is necessary to assume a high furnace efficiency. It would seem that 1,200 kw.-hr. per 2,000 lb. of ore would be a sufficiently brilliant realization.* Even such a one would put electric smelting upon a sound basis in so far as power consumption is concerned.

Cost of Smelting.—The art of electric zinc smelting is still too much in its infancy to permit of much more than speculation respecting the probable cost. The only data of operation on a large scale continued for a considerable period of time that are available are those of Trollhättan, where electric power, labour, etc., are obtained very cheaply. If the Trollhättan figures be applied to the conditions of power at $20 per horsepower per annum, labour at $3 per eight hours, and other elements in proportions, electric zinc smelting on the basis of the metallurgic results obtained there would be out of the question. If it becomes possible to smelt with 1,200 kw.-hr. per ton of ore, to reduce materially the labour and electrode costs, and to extract 90% of the metals, there will be some chance.

As to the probable cost of plant we are still greatly in the dark. It is hardly to be expected that the electric plant will be of any less cost than the coal fired. Comparing operating costs, there will be the same expense for administration, general charges, yard labour and roasting in each case. Heating coal

*It may be possible to economize electrical energy by the direct use of coal or gas for part of the process. Perhaps the carbon monoxide discharged from the condenser may be utilized. However, I do not consider knowledge of electric zinc-ore smelting to be far enough advanced yet to warrant any calculation of this kind.

will stand against electric current, say 1 to 1.5 tons against 1,200 kw.-hr. The relative consumption of reduction coal is uncertain. The retorts of ordinary practice will be dispensed with, but instead of them the electric smelter will have an electrode expense. The relative cost of repairs and renewals and miscellaneous supplies is uncertain; also the matter of labour. At first thought it seems that the labour on a furnace smelting 6,200 lb. of ore per day ought to be less than in connection with 80 Rhenish retorts or 150 Belgians, but the experience at Trollhättan does not yet confirm that idea, though, no doubt, improvement will be realized in this particular.

Limitations.—In the report of the Commission to Investigate the Zinc Resources of British Columbia, published in 1906, I made the following remarks:

> The successful smelting of zinc ore in the electric furnace is a matter which depends chiefly, indeed I may say solely, upon the cost of the process. De Laval has shown that it can be done. The doing of it profitably is quite another question. This is dependent chiefly upon the cost of power, the electrical efficiency of the furnace, and finally upon the purely metallurgical difficulties that pertain to the reduction of zinc oxide and the condensation of the metallic vapor.
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> From the present development of electrothermic smelting of zinc ore, and the calculations respecting it, the following conclusions may be drawn:
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> 1. Electric smelting will never displace ordinary smelting, if it be necessary to generate the power from coal.
>
> 2. Electric smelting may be, in the future, economically conducted at places where very cheap hydro-electric power is available.
>
> 3. Aside from the question of power, up to the present time certain peculiar and serious metallurgical difficulties in electric smelting have not been satisfactorily overcome.

During the six years that have elapsed since those words were written, much has been learned respecting their subject, but as generalizations they remain as true to-day as they were then.

The successful achievement of smelting zinc ore in an electric furnace will probably be the result of learning how to run the furnace; i.e., how to control the process, rather than of any distinct invention. I conceive that the electric zinc-ore smelting furnace will be an apparatus of general character, such as is the blast-smelting furnace for lead ore, etc. This is to say:

Lead ore may be successfully smelted in many forms of furnaces of the same generic character, but with variations in their lines that are of important economic effect. Once it has been learned how to run an electric furnace for zinc smelting, I believe it will be found that the process can be conducted in many forms of furnaces conforming to the general type, wherein the principle will be the same although the economic results may differ widely.

RECENT IMPROVEMENTS AND ADDITIONS TO THE SMELTING PLANT OF THE CANADIAN COPPER CO.

By David H. Browne, Copper Cliff, Ont.

(*Annual Meeting, Toronto,* 1912.)

In the year 1910, the Canadian Copper Company had in operation ten stands of acid converters. The shells were 84 in. x 126 in., and were lined with the usual mixture of quartz and clay. In each shell were eight tuyeres, one inch in diameter and six inches apart. The centre or mould around which the lining was rammed was oval in shape, 3 ft. 4 in. high, 5 ft. x 2 ft. 6 in. at top and 4 ft. 6 in. x 2 ft. at the bottom. Each shell consumed about 3,000 cubic feet of free air per minute at 9 to 11 lbs. pressure.

The production of matte from these shells depended largely on the grade of furnace matte with which they were supplied. On a 36% furnace matte one lining lasted for about eight hours blowing time and produced seven tons of finished bessemer matte, 80% copper-nickel. On a 30% furnace matte one lining was good for about 5.3 tons bessemer matte.

As the amount of metal lost in furnace slag depends very much on the grade of furnace matte made this pointed to the desirability of producing lower grades of furnace matte with cleaner slags. This threw on the converters every year an increasing burden. The converters received lower grade furnace mattes, containing not only less copper-nickel but more iron. In a 40% furnace matte one pound of copper-nickel is accompanied by 0.88 lbs. iron, in a 30% matte by 1.34 lbs. iron, and in a 20% matte by 2.4 lbs. iron.

As this iron is removed by oxidation and combination with silica to form a slag, and as the amount of air passing into the converter is a fixed factor, practically 3,000 cubic feet per minute, it is evident that lower grade mattes take longer to blow than higher grades. When using a 36% furnace matte about one

hour and five minutes blowing is required to produce a ton of 80% bessemer matte, while with a 30% furnace matte an hour and fifty minutes is required.

Furthermore, the amount of scrap, or material thrown out of the mouth of the converter while blowing is a factor of the time of blowing. The amount thrown out by the blast is about the same per hour. Therefore, as the furnace matte becomes of lower and lower grade the production of the converters becomes less and less, first, because they have more iron to remove and need longer time to do it, and second, because during this longer time they slop out more and more material on the floor.

These considerations decided the Canadian Copper Company to discard this type of acid converters and to substitute basic converters, such as had been installed by Smith and Peirce at the Garfield plant of the American Smelting and Refining Co.

A basic converter is simply a cylinder lined with magnesite brick. The function of the converter is exactly the same as in the acid converters. Air blown in through the tuyeres passes through melted matte and oxidizes iron. The oxide of iron combines with silica and forms a slag. The difference lies in the fact that in the acid converters the siliceous material is rammed in to form the lining of the converter. The iron attacks this lining and melts it off to get at the silica, so that after a few hours blowing the lining is all cut away and the shell must be relined. In the basic converter the lining consists of basic bricks and the quartz or other siliceous material is dumped into the converter on top of the matte from time to time as the converter requires it. The magnesite bricks which form the lining are very slowly worn away above the tuyeres, but a basic converter will make six or seven thousand tons of bessemer matte before it requires repair, while an acid converter requires relining after making six or seven tons.

In March, 1911, the first basic converter was blown in. During the remainder of the year the acid stands were taken out and basic converters put in their place. At present all the acid converters have been removed and their places taken by five basics.

The new basic converters at Copper Cliff.

Interior of Converter building, at Copper Cliff.

These basic converters are 37 ft. 2 in. long by 10 ft. in diameter, outside measurement. They turn on four tread rings 12 ft. in diameter. The stack or opening in the roof for the escape of gas, is in the centre of the cylinder instead of at the end, as in the Garfield plant. There are 44 tuyeres, 1¼ in. in diameter and 7 in. apart. There are no tuyeres directly under the stack. The length inside the lining is 33 ft. 3 in. The bottom is 2 ft. thick, the back or tuyere wall is 18 inches and the front 15 inches thick. The roof is a 12-inch arch. The brick directly around the tuyeres is 24 inches thick.

These converters have two openings or spouts in the front wall opposite to but above the tuyere line. The shell is turned down to pour slag and matte from these openings or turned back to blow by means of two wire ropes which surround the shell on either side of the central stack. These ropes are fastened to a hydraulic piston working in a horizontal cylinder, having a stroke of nine feet.

As the usual hydraulic equipment would not be suitable to the climate of Northern Ontario, oil is used instead of water, since oil remains fluid at low temperatures.

This is moved in the cylinders by air pressure. Two tanks are provided, one for regular use, one for emergency. These tanks are of ¾ in. steel 4 ft. diameter by 15 ft. high. Into these tanks a small amount of oil is pumped, and the space above the oil is filled with air at 75 lbs. pressure. An electrically driven pressure pump now forces more oil into the cylinders, compressing the air to 300 lbs. pressure. At this pressure the pump automaticaly stops. When it is desired to turn down the converter a valve is opened on the converter platform, allowing the oil to pass to one side or the other of the hydraulic cylinder, moving the piston and so by means of the rope tackle turning the converter as desired. In this operation the air in the tank above the oil expands and loses pressure. When the pressure in the tank falls to 200 lbs. the oil pump starts automatically pumping oil into the tank till the pressure rises to 300 lbs.

As the entire equipment of the plant is electrically driven it is manifest that if for any reason the power went off the line the converter blower would stop blowing air into the tuyeres. The

matte would then run back through the tuyeres, as the mechanism for turning the converter down, being also electrically driven, would be useless. To avoid this a spare tank always contains oil under 300 lbs. pressure. This spare tank is connected to the hydraulic cylinder by a valve which is held closed by a solenoid brake. The fly wheel of the converter blower is of sufficient size to keep the engine turning over and delivering air for perhaps 15 to 20 seconds after the power goes off. The solenoid brake is actuated by the electric power, and the moment the power goes off the solenoid brake drops, opening the valve, and admitting oil to the proper side of the cylinder to turn the converter down.

It sometimes happens that a thunderstorm twenty-five miles from Copper Cliff will cut off the current on the power line. The safety device above described, being absolutely automatic and entirely separate from the regularly used turning device has proved quite satisfactory.

The basic converter takes an initial charge of about 60 tons of furnace matte. About ten per cent. of quartz rock, previously dried, is dumped into the converter, and the blast is turned on. Blowing is done entirely by the clock. The charge is blown from one-half to three-quarters of an hour and is then turned down to skim slag. While the slag is being poured off, five or six tons of furnace matte is poured into the converter. After the slag is poured about three tons of quartz or siliceous ore and quartz are added and the shell is blown for another fixed time. The length of the blow, the amount of slag removed, the weight of matte added after each skim and the per cent. of flux required are all factors of the grade of matte and have to be determined by experience.

The blowing and the addition of matte are kept up until there remains in the converter seventy or eighty tons of finished product. This may require from 300 to 400 tons of furnace matte and from 30 to 50 hours' blowing time, depending on the matte grade. The finished matte is then cast into moulds, and the cycle of operations re-commences.

The basic converter has several advantages over the acid converter. The units are very much larger. This simplifies the

problem of dealing with large quantities of matte. There is practically no material slopped out of the converter during the blow, and hence less furnace matte is required to produce a ton of bessemer matte. The slag made is lower in silica which means economy of flux. The converter slag contains less copper-nickel than the acid converter slag; but since all the converter slag has to be re-treated, this of itself is not material. As a whole the operation of converting has been much simplified by the change.

During the last few years about fifty thousand tons of flue dust have been recovered from the blast furnace dust chambers. Several attempts have been made to briquette or sinter this flue dust so as to make it useful as a blast furnace charge; but these have proved ineffectual, either by failure of the method or by extravagant cost. The flue dust has therefore been set aside in piles to wait the building of reverberatory furnaces. There has been a similar accumulation of green ore fines from the mines, material under ¼″ diameter which is too small for the blast furnaces.

In the year 1911 The Canadian Copper Company commenced the erection of two large reverberatory furnaces. The first of these was blown in at the end of December, 1911.

These reverberatory furnaces are interesting as being the first furnaces designed to burn pulverized coal. Experiments in the use of pulverized coal had been previously made by Chas. Shelby at Cananea, and by S. S. Sorensen at the Highland Boy smelter; but while these experiments proved that this method of coal firing could be used, local conditions prevented its adoption. In neither case was the furnace specially designed to meet the requirements of this fuel.

The furnaces built at Copper Cliff are 112′x19′ hearth area. The side walls are 27″ thick. The roof is 20″ for the first 35 feet near the coal burners and 15″ thick for the rest of the way. The extreme height inside is 6 feet. The bottom is an inverted arch of magnesite brick with a spring of 12 inches. The spring of the roof arch is 19 inches, one inch rise to the foot.

The foundation of these furnaces was made by building a trestle about 14 feet high, and pouring furnace slag from this, to build up within the outer walls a solid block of slag ten feet

above the yard level. On this foundation the side walls of the reverberatory furnaces were built. Slag was poured inside these walls to form a hearth or furnace bottom about two feet thick. By this a solid mass of slag about 12 ft. thick was formed under the furnace. Between the furnaces openings were formed by concrete retaining walls, so as to leave tunnels entering the slag foundation at the yard level and at either side of each furnace. Through these tunnels the melted converter slag is brought to the reverberatory and matte is taken back.

The hearth of the furnace is formed by levelling up the poured slag bottom with concrete so as to provide an inverted arch of the same curve as the magnesite brick lining. On this form one layer of fire brick was laid flat, 2½″ thick. Over this 9″ magnesite brick was laid. This brick hearth was laid in a mixture of ground magnesite and linseed oil. Expansion strips of wood were placed between every six courses. The expansion allowed is ¼″ to the foot.

The side wall is of silica brick 18″ thick. On this the roof rests. Inside this wall a flash wall of magnesite 9″ thick is built. This does not support, but is brought close up to the roof. The tap hole is so placed as to retain 12 inches of matte in the hearth. so that the bottom is always protected by a pool of matte.

Slag is removed, not at the front of the furnace as is usually the case, but at either side of the furnace, where the side walls commence to narrow in, about 11 feet from the front of the furnace. The space at the front usually occupied by the slag door, slopes up gradually from the hearth to form a straight outlet for the products of combustion. The area of the throat is about 27 square feet. The gases meet no obstacles whatever, but pass straight into a cross flue 6′ x 9′, which is covered by cramps. This flue is 70 feet long. and leads to the main or dust chamber flue. The main flue is 15x19x177 ft., and connects with the stack. The stack is 17 ft. 2 in. diameter at the bottom, 15 ft. 4 in. diameter at the top, and 200 ft. high.

At the fire end of the furnace two sets of charging bins are provided. These are used to drop flue dust, ore fines and other pulverized material into the furnaces. Each bin has five hoppers discharging by slide gates through the roof.

General view of reverberatory furnace building at Copper Cliff.

Interior view of new reverberatory furnace building at Copper Cliff.

The most interesting part about the reverberatory is the method of firing. Coal is dropped from the trestle into storage bins. Out of these bins it passes through a coal cracker on to a conveyor belt. This coal ½ in. in size, and under, is carried by this conveyor belt to the coal grinding room and dropped into a bin. From this bin it is fed by a screw conveyor to a Ruggles Coles dryer. The dry coal is elevated into bins from which it drops into two Raymond impact pulverizers. This grinds the coal to the finest powder, most of it passing a 200 mesh screen. This pulverized coal is sucked up by a fan into a separator on top of this building, and passed by screw conveyors into the reverberatory building, and dropped into bins at the end of the furnaces. From these bins it is taken by five variable speed screw conveyors 4 in. in diameter. These deliver the coal into five burners, dropping it in front of nozzles which carry air from a fan. The air blast sends the coal into the furnace in the form of a cloud or spray of dust which burns just like oil fuel. Each burner can be run independently and the amount of coal or air can be varied at will.

The slag from the converter building is brought to the reverberatory furnace in ten ton pots by a locomotive, which enters the tunnels between the furnaces. Through openings in the roofs of these tunnels the reverberatory cranes pick up the slag pots and pour the slag through an opening in the side wall of the furnace. The slag skull being left in the pot, the pot is set back on its truck in the tunnel, and reverberatory matte is tapped into it. This reverberatory matte is taken back by the locomotive to the converter building and charged into the basic converters.

This reverberatory building was put in operation before the bins were completed. At present flue dust and green ore fines are charged through the side doors by hand. As the charge is wet and frozen the amount charged is at present low. The coal firing system, however, is quite satisfactory. No difficulty is experienced from coal ash. A small amount of ash settles in the flue near the end of the furnace. This ash is removed through doors about twice a week.

As the plant has been in operation only a few weeks and under abnormal conditions, no comparisons can be made with

Western practice. It may be stated, however, that the system of firing is quite satisfactory, and that with the charge put in through the bins it is expected that this method of firing will prove much cheaper than burning coal on a grate. There is no loss of fuel efficiency. All the carbon in the coal is consumed. The ash offers no difficulty and the heat of the furnace is maintained uniform.

After the furnace has been in operation a few months under normal conditions some comparisons may be instituted. Present indications are that these comparisons will show that this system of firing has many advantages over the grate firing of coal which has heretofore been the customary practice.

TOOL STEEL FROM TITANIFEROUS MAGNETITE BY EVANS-STANSFIELD ELECTRIC FURNACE PROCESS.

By J. W. Evans, Belleville, Ont.

It is not practicable to smelt titaniferous magnetites in a blast furnace where the percentage of titanium is more than about three per cent. without the addition of other ores. It is also practically impossible to obtain any other product than pig iron from the blast furnace. When the writer began a series of experiments in the years 1905 and 1906, with a view to the manufacture of a saleable product from the titaniferous magnetites of Ontario and Quebec, it was evident that for the direct production of steel from these ores the electric furnace only could be used. The work carried on by Stassano at Turin, in the production of steel from ore, showed that a mild steel and steel suitable for castings could be made directly from iron ore in an electric furnace. The furnace designed and used by Stassano consisted of a chamber lined with magnesite brick, provided with two or more lateral electrodes, which meet in the middle, and produce an electric arc. The iron ore was mixed with charcoal, coal and flux and was briquetted and charged into the furnace. The heat of the arc enabled the ore to be reduced to metal and the whole was melted down. In order to stir the charge and dislodge any material that might adhere to the walls, the furnace was placed slightly out of the vertical and was caused to rotate on a circular track so that the charge was continually stirred. The process was successful technically and yielded a steel of good quality; but it was too expensive to compete with existing processes for the production of structural steel or steel rails, and Stassano now uses his furnace for the production of steel from pig iron and iron ore.

It occurred to the writer that if a mild steel and steel suitable for castings could be obtained directly from Italian iron

ores, there was no reason why a high-grade tool-steel could not be made directly from our titaniferous iron ores. With this object in view, experiments were begun at Deseronto in 1905, and it was found that this assumption was correct. A furnace was designed utilizing both lateral and vertical electrodes in order that the charge might be at first melted and when sufficient slag had been formed, the vertical electrodes could be used and an arc formed between them and the molten material. This arrangement of electrodes is more economical and also protects the roof of the furnace. By proportioning the amount of charcoal it was possible to obtain steel of any desired carbon content, and small tools made from steel smelted in this manner were found to have exceptionally good cutting properties.

The next question to determine was whether the process could be applied commercially. In the first experiments, a mixture of ore, charcoal and limestone, was used without briquetting. The experiments were continued and larger furnaces built from time to time, until in the year 1909 a furnace was constructed sufficiently large to yield bars of steel weighing from five to seven pounds. This was in operation in a small plant at Belleville. During the month of September, 1909, Dr. Alfred Stansfield visited the plant, and was much interested in the results obtained by this process, but suggested several improvements, of which may be mentioned the briquetting of the charge, and the utilization of the waste gases from the furnace for pre-heating and partially reducing the ore. While Dr. Stansfield was in Belleville a pre-heater was built above the furnace, which, in operation, showed a saving both in the time required and in the amount of electric power consumed for the reduction and melting of the charge. A patent was applied for and obtained in United States and Canada on this pre-heater.

Dr. Stansfield read a paper entitled "Tool-Steel Directly from Iron Ore in the Electric Furnace" at the annual meeting of the Institute in Toronto in 1910, and since then has constructed at McGill University a larger furnace with a capacity of more than one-quarter of a ton of steel per twenty-four hours. This furnace has been built with a pre-heater, and some fifteen or more runs have been made with it; producing several hundred

pounds of fine tool-steel from titaniferous magnetite from the Orton Mine.

The results of these runs have shown:—

1. That it is possible to make a superior quality of tool-steel directly from titaniferous magnetites at a very small cost. The cost in a 5-ton furnace will not be more than three cents per pound.
2. That steel of any required carbon extent can be made by regulating the quantity of carbon used in the briquettes.
3. That a fine steel can be made directly from this class of ore without the addition of any deoxidizer, such as ferro-manganese, ferro-silicon, etc.
4. That high carbon steels made by this process are almost equal to the high-speed, air-hardened steels, which cost in the neighbourhood of sixty cents per pound.
5. Tests have been made of steel from this furnace at the rolling mills in Belleville in re-turning chilled rolls. This is one of the hardest tests for tool-steel. Steel-tools cast directly from the furnace, without any treatment, such as rolling or hammering, stood the test equally well as air-hardened steel, for which the company pays 60 cents per pound.

An estimate of the cost of making tool-steel in a 5-ton plant, using Orton ore, or ore of a similar composition, is as follows, for five tons of steel:—

1.	The amount of ore will be 12 tons, at $4.00	$48.00
2.	The ore is crushed to about 1-20 inch mesh, costing say 50 cents per ton	6.00
3.	The ore is put over a magnetic concentrator to reject gangue matter, etc., 10 cents per ton	1.20
4.	Total cost of 10 tons of dressed ore	$55.20
5.	1.6 tons of charcoal at $10, and $2 for crushing	19.20
6.	0.8 tons of lime at $3 and 50c. for crushing	2.80

7.	0.7 tons of pitch at $10	7.00
8.	0.7 tons of tar at $10	7.00
	Total cost of charge	$91.20
9.	Briquetting the charge at 50c. per ton	7.00
	Total cost of 13.8 tons of briquettes for 5 tons of steel ingots	$98.20
10.	Possible cost of ferro-silicon, etc., added to steel	1.50
	Total cost of charge and additions	$99.70

REDUCTION AND SMELTING.

1.	The briquettes are to be heated, and the iron reduced as far as possible to metal, in towers (Stansfield patent) using mainly the gases from the distillation of the briquettes, and from the electric furnace. Allow, however, 5 per cent. of coal for starting, and an equal amount for maintenance of the pre-heater. 0.7 tons of coal at $4.00—$2.80 and $2.80	$5.60
2.	Electric power needed.—Actual power per ton of steel smelted will probably be as low as 0.20 h.p. years. Add 20 per cent. for re-smelting scrap, 10 per cent. for transformer losses, and 10 per cent. for standby losses, etc. Set final cost at 0.30 h.p. year at $15	22.50
3.	Furnace repairs, say	5.00
4.	Electrodes, say $1.50 per ton of steel ingots	7.50
5.	Moulds, ladles, etc., say	1.00
6.	Management and Labour—	
	Manager at $10.00	10.00
	Two foremen at $5.00 each	10.00
	Ten labourers at $2.50 each	25.00
	Office work and maintenance of office	10.00
7.	Interest and depreciation at 10 per cent. per annum on $30,000	13.00
	Reduction smelting management, etc.	$109.00

Cost of charge and additions (brought forward) ...	99.70
Total cost for 5 tons of steel ingots	$208.70
Cost per lb. of steel ingots	0.0209

The total cost of a plant consisting of two five-ton furnaces would be in the neighbourhood of $30,000, itemized as follows:—

Building frame covered with corrugated iron	$3,000
Transformers	3,700
Instruments and switchboard	800
Briquetting machine	1,700
Rock crusher	650
Fine Grinder	1,070
Mixing machine	800
Two five-ton furnaces	8,000
Cable connections	725
Fifty horse-power motor	875
Stock of electrodes	1,000
Shafting and hangers, etc	250
Weigh scales connected with tracks	80
Cars, rails, etc	550
Screw conveyor	600
Magnetic separator	2,000
Water connections	200
Stock of magnesite and silica brick, extra water connections and electrodes	3,000
Incidentals	1,000
Total	$30,000

Compared with a blast furnace an electric furnace is very simple in construction, nothing more being required, but a fire brick shell strengthened with Angle iron, lined inside with magnesite, and silica brick, and having water jacketed, electrode holders. No blowing engine is required, or hot blast stoves or other machinery, and the product from the electric furnace is a high-grade steel in one operation.

The market for tool steel in Canada is much larger than is generally supposed, and the amount of high-speed steel used, although only about one-eighth the quantity of the ordinary grades of carbon steel, has a greater money value. The writer has, during the winter, communicated with nearly all the large users of tool-steels, and finds that they spend on the average rather more for high-speed than for ordinary carbon steels. This does not include drill steels.

All this steel is imported into Canada at the present time, although we have large deposits of titaniferous iron ores from which excellent steel could be made.

The analysis of the Orton mine ore is as follows:—

	Per cent.
Iron	54.00
Titanium	7.50
Vanadium	0.11
Nickel	0.31
Sulphur	a trace
Phosphorous	0.014

together with some manganese and some chromium.

This ore seems to be particularly suitable for the production of steel. It smelts down quickly and quietly in the furnace, and yields a steel, which is uniform in grade, fine in section, and is free from blow-holes. Not only can this process be used for the making of tool-steel, but for the production of sound steel castings, for which there is a large market.

A company has been formed in Belleville to erect a 1-ton plant, and ore for this plant is now being obtained from the Orton mine.

HARDINGE CONICAL MILL.

By H. W. Hardinge, New York.

(*Annual Meeting, Toronto,* 1912.)

Simple as the subject of crushing appears to be, it has as many phases as the materials to be crushed. To the layman, an ore is an ore, a rock a rock; but to the geologist or metallurgist, the words ore and rock are generic terms without special meaning, in fact the more he studies them, the less significance have the words, for rocks are more than legion in their complexity and subject to as many variations in combination of constituents, as is the alphabet capable of combinations of words. In the rock alphabet, there are upwards of seventy or more letters, (elements), from which the mineralogist may, and does form his words. The subject of crushing is reaching out for the cube and square roots of combinations of figures composed of these elements; hence, to make a proper division, a correct division, without too great a waste of energy, one must have a very wide knowledge and experience, and the more we study the subject, the more we learn how little we know of that first prime move to make in the winning of the metals by separating them, through division, from their rocky storehouse.

Crushing is not confined to the efforts of the metallurgist alone, but it has an equally wide range, or even wider range, as it finds its way into commercial industries, so numerous and varied that though we may have given years to the subject, in the same manner as have all metallurgical investigators, our learning is but slight.

Crushing or dividing may possibly be subject to two or three general mechanical principles. Dynamic action due to impact, when the energy forces rend along the lines of least cohesive resistance, or by pressure strains rending through slower separation of the crystals, deforming the mass; or by abrasion and separation from the surface inward. The first can be defined as

a blow from a hammer, the second by compression in the jaws of a crusher, but the third is more difficult to define, because of its limited employment owing to its waste of energy, but might be likened to the wearing away of the faces of millstones. Nature in the manufacture of soil from the rocks has employed all three, but evidences would tend to show that in finest division she has been prodigal of her energy, for such fine division has been mainly produced through abrasion, except in the case of the chemical separation in the formation of the many clays. It is with this fine division and how most economically it may be produced, that we, as metallurgists, are at present interested. For years the "California" stamp has been the most widely used device for the crushing of ores, and held its position in the first rank because fine grinding, as understood at present, was not a necessity, but with the advance from mechanical separation of the gold and silver content of ores, to that of chemical separation, the necessity for finer and finer grinding in order to liberate the mineral has progressed much faster than the mechanical means to do this fine grinding, so that to-day the stamp is slowly giving way to other applications of crushing energy. We very well remember when in 1895 and '96 we were shown the first adaptation of the pebble or tube mill, and when told what it would do in the way of fine grinding, there was no hesitancy on our part in declaring that the claims were absurd, but shortly after the small mill was started, we were converted, and became the strongest of advocates of the pebble mill for still further reducing what at that time was considered fine grinding, mainly by stamps and rolls.

In this tube mill was a principle of step reduction not obtained by any mechanical device before that time. The stamp had reached its possible limit because it, with every blow, receded farther and farther from efficiency, owing to increasing disparity of size and weight, between reducer and particle. It was comparatively a sledge hammer which had broken the rocks into chunks (acting on the spike) and again into bits (acting on the nail) and was continuing, with its application of single force unit, expending the greater part of its energy in compression and a readjustment of particles or bits, to attempt

still further breaking up or disintegration (acting on the tack). Is it not reasonable that we should now use the tack hammer —the pebble in the pebble mill? It has taken a long time to bring us to a recognition of the fact that to economize our energy, the units of force must correspond to the units of matter being acted upon. The well known rule of physics particularly applies here, i.e.: The energy expended in producing fracture varies as the volume.

If, in the breaking of a two inch cube of ore by a single drop of a 1,000 pound stamp, we divide the mass into quarter inch cubes, we perform a reduction of 1-500 and then, assuming

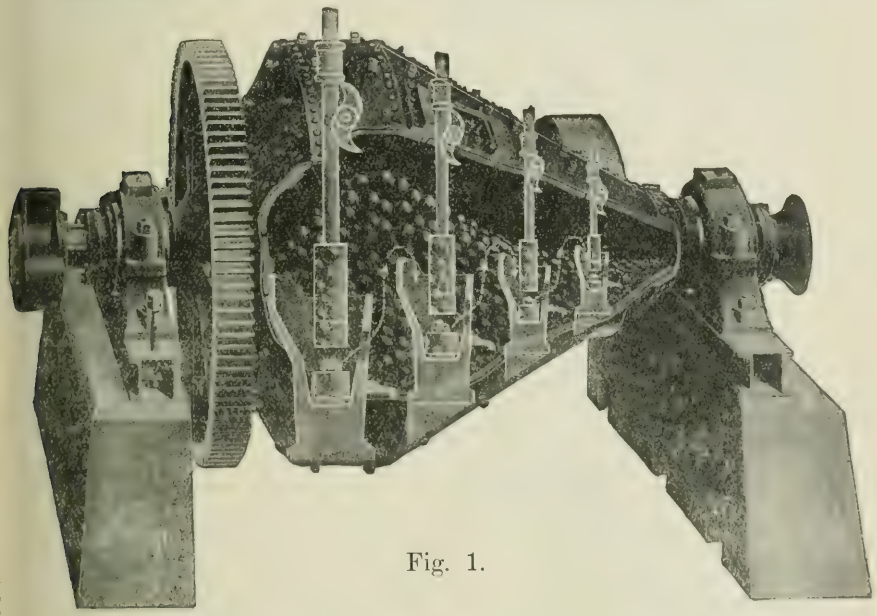


Fig. 1.

the energy has been well applied, the further reduction should be in the same ratio of energies to work, but instead of reducing the stamp weight to 1-500 of the original, or a 2-pound stamp, the work continues with the initial weight of the stamp —the sledge hammer is doing tack hammer work. One would not think of weighing an assay ton on the same scale that was used in weighing the ore shipment, and yet this is comparatively what is done when the stamp is called upon to reduce a

2-inch cube to pass 20 mesh. The relation of the assay ton to the avoirdupois ton is 29,000 to 1. In the crushing of the 2-inch cube to 20 mesh the relation of division is 64,000 to 1. These discrepancies, while impossible at present to reconcile by adequate machinery, are certainly matters worthy of at least the consideration of every metallurgist. It was the recognition of this error in the application of crushing forces in our metallurgical work which induced an effort for an improvement without corresponding complication. We feel we have made some advance toward this end in bringing out the Conical Ball and Pebble mill, a device which fairly well, and automatically, adjusts power to results desired, as illustrated in cut, which likens the reduction of weights within the mill to reducing weights of stamps as shown in shadow.

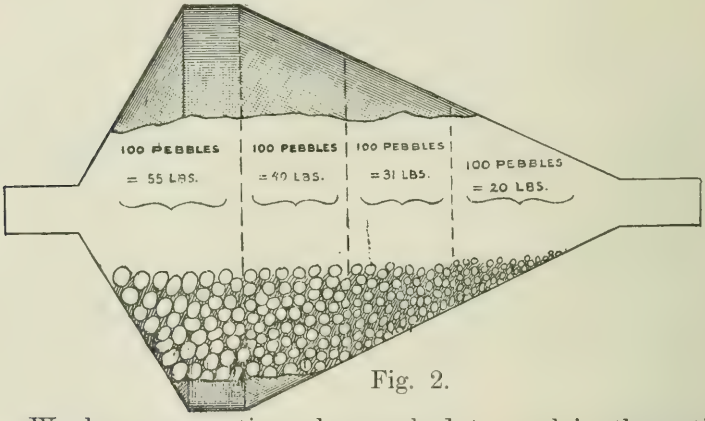


Fig. 2.

We have many times been asked to explain the action within the conical mill, and the cause for its sizing action—not an easy matter. Many articles have been written on the theory of the Pebble and Ball mill. These in turn have produced suggestions and practices resulting in changes of length, diameter, feed, discharge, speed of rotation, charge of pebbles, size of pebbles, etc., etc.

Improvements have been left to the discretion of the machinery designer, who, as a rule, has but little knowledge of the specific technical requirements of the metallurgist, or of where the economic limit begins or ends. We could cite many in-

stances where a lesser expenditure of energy would have improved metallurgical results, and it should be the aim of the metallurgist to fit his machinery to his ore, and not endeavour to adapt his ore to any specific machine. Realizing these conditions, we thought we saw in the conical form of mill a device which could be made more or less adjustable to many classes of ores—from granulation for concentration to sliming for cyanidation, for in the zone of largest diameter we have all the features necessary for the greatest application of energy, e.g., the largest pebbles or balls, the greatest superincumbent weights, the greatest height of fall and impact due to greatest peripheral speed, and in this zone are found the largest particles of material to be reduced, thus admitting of a much coarser

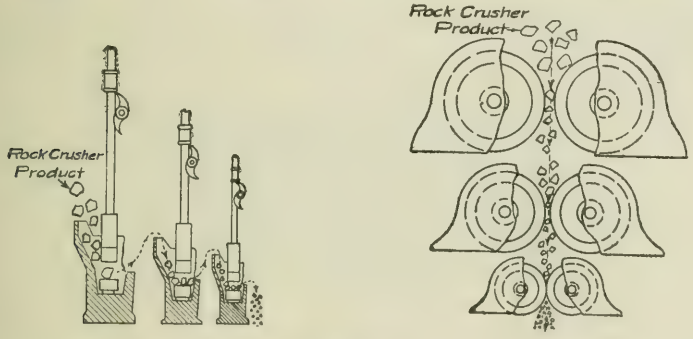


Fig. 3.

feed than would otherwise be possible if the crushing forces were not segregated. After a first division or reduction, these particles, through the action of the displacement, dependent upon their relative mass, travel up the cone, through constantly decreasing zones of size and weight of crushing bodies, as well as decreasing energy due to reduction of peripheral rotation speed proportionate to the division of the particles in passing through successive zones, as illustrated in the accompanying diagram.

Step reduction is not even supposed to be new, either in idea or application, for it is applied in successive sizes of rolls where a reduction of 1:8 is about all that is sought. This stage roll reduction is practicable (by rolls in series), for the

crushed material issues by gravity and if work is not performed, energy ceases (except for bearing friction), but the roll has an economic limitation which we believe ceases at about half inch mesh when the roll has been in opeartion a short time and corrugations have commenced to form.

On the other hand, step reduction by stamps is practically impossible, for the issue is dependent upon mechanical assistance to remove the divided material from the die after crushing, and if the product of the first blow is not removed the further reduction is not in proportion to the power expended, as the already divided material interferes with subsequent work by forming a cushion. Different from the roll, the stamp consumes the power in the lift, irrespective of the work performed; in fact, if the force is not expended in economic work it is expended in destructive action on the die and foundation.

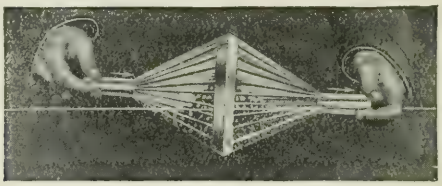


Fig. 4.

Stamps of successive reduction in weight are theoretical only. Above we show (Fig. 3) sketches of these two practical (rolls) and impractical (stamps in series) principles of step reduction.

While we do not claim that the conical mill more than approximately overcomes this great discrepancy between energy and work performed, it certainly applies its forces in a more economical manner, reducing the power as the energy requirement is also reduced.

In addition to these automatic adjustments of work to mechanical energy, the device is subject to a still further regulation by changing the axis from the horizontal to different inclinations from the horizontal, which will cause the finer particles to travel toward the outlet much more rapidly, and consequently be subject to lesser action of the grinding bodies than when in the horizontal position, which latter position is

assumed for the finer grinding. The working machine is provided with means for making these different adjustments.

A practical illustration of this action can easily be obtained by placing two glass funnels base to base after partially filling them with gravel and fine dry sand, joining them with cement or adhesive tape, then evenly revolving with the axis horizontal. The experiment may also be made when the axis is at a slight inclination from the horizontal, as illustrated in Fig. 4. The result will prove both curious and interesting because unexpected.

For fine grinding, it is found advisable to elongate the cylindrical portion.

The old style or cylindrical form of tube or pebble mill is built in lengths of approximately 20 feet, throughout which length the grinding pebbles are indiscriminately distributed; thus at both ends may be found pebbles of same or very dissimilar sizes, as the cylindrical mill has no selective sizing action. The larger pebbles at both inlet and outlet ends waste their energy by acting on the smaller pebbles as well as on the material undergoing disintegration. As an illustration of this waste of energy, we will assume that a 3-inch pebble is acting upon a ¼-inch (4 mesh) particle at the inlet end, in which case the relative size of pebble or crushing force to the particle is 1:896 or practically 1:1000. If in the passage through the mill this particle is reduced to 50 mesh and is still being acted upon by a 3-inch pebble, then the relation would be 1:1,750,000, or a power of 1,750 times greater than necessary. It may be contended that the crushing surfaces of the pebbles are acting upon several particles at the same time, which may be true, but hardly to such a degree as to materially affect the comparison above mentioned.

One great advantage of the conical form of mill was outlined in recent court evidence in the following statement by one of the oldest manufacturers of tube mills, and referring to cylindrical mills: "It has been a well-known fact for a great many years that no grinding takes place at or against the head of a mill." This defect is, of course, entirely overcome in the conical mill.

A great deal of experimenting has been done with cylindrical tube mills to obtain the most efficient r.p.m. speed, the size of pebbles, as well as size of feed. Various results have been obtained and recommended, but we know of no formula that can even approximately fit all conditions, for here again enter the varying factors of quality and size of material fed. While a tube mill of a certain length, diameter, charge of pebbles, size of pebbles and quantity of water and r.p.m. may

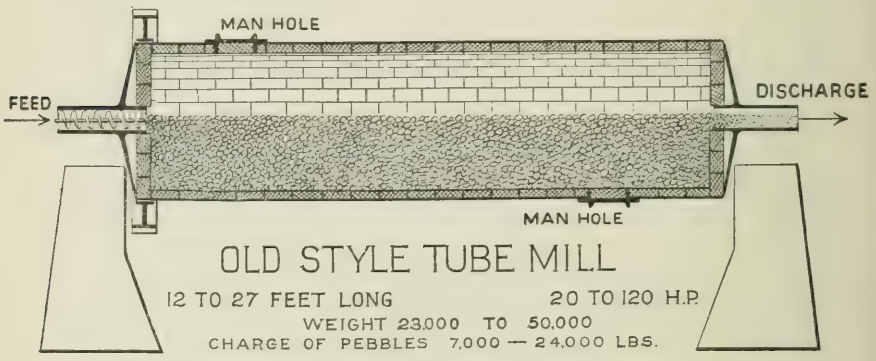


Fig. 5.

be economically adjusted to a particular ore, it carries no certainty with it that it will be correct for another ore, any more than a particular analytical formula will determine the chemical constituents of all ores.

Even the Conical mill, subject as it is to varying adjustments, produces vastly different capacity results when working on different ores, as will be seen by comparing the following performance of 8-foot Hardinge mills operating under

	Mesh	On 40	On 60	On 80	On 100	On 200	Thru 200	Tons per 24 hours
Calumet & Hecla Mining Co.	Per Cent.	2.0	2.1	6.5	6.0	43.0	40.8	45.0
Federal Mining & Smelting Co.		4.0	7.5	7.0	10.5	18.0	53.0	99.4
Miami Copper Co.		16.0	15.5	8.9	7.7	13.8	38.1	180.0

similar conditions of power, pebble charge, r.p.m., etc., in three of the largest concentrating plants in the United States, under the supervision of experts of the highest metallurgical order, and though of widely different capacities, as shown, each plant manager reports the results as highly satisfactory. In the first and third instances Chili mills were formerly used, and in the second, Huntington mills, to do the same work. The feed in each instance was practically of same mesh, being through 5 mm. on 1 mm.

Speed of Pebble Mills.—Authorities vary widely as to the best speed for pebble mills, but in no instance outside of our

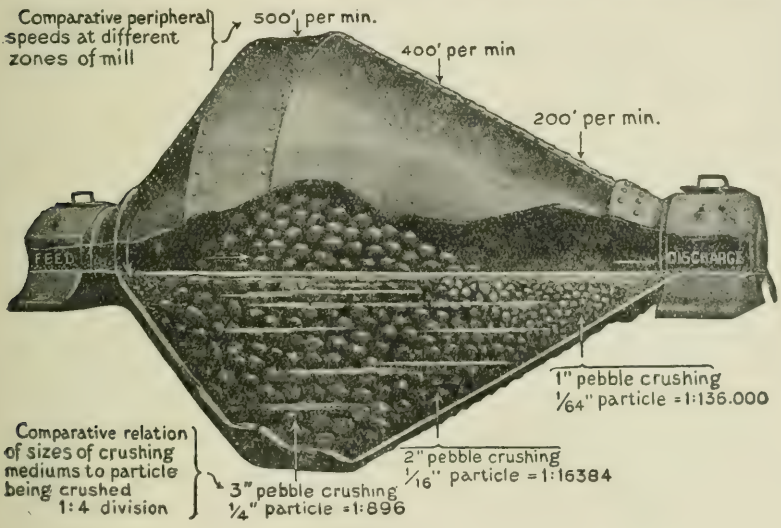

Comparative peripheral speeds at different zones of mill
500' per min.
400' per min
200' per min.
FEED
DISCHARGE
1" pebble crushing
1/64" particle = 1:136.000
Comparative relation of sizes of crushing mediums to particle being crushed 1:4 division
2" pebble crushing
1/16" particle = 1:16384
3" pebble crushing
1/4" particle = 1:896

Fig. 6.

own practice do we know of their being run above 500 peripheral feet per minute, but range from 400 to 450 feet, a speed sufficient only for a free movement of the pebbles, while in the conical mill we find the most effective r.p.m. is one which will give 560 feet at the largest diameter where the greatest work is being done by the largest pebbles on the largest particles, producing a cascading effect, relative to hundreds of small stamps. This maximum of peripheral speed and energy force gradually reduces, in stages or zones, foot by foot until

its effective action is fairly commensurate with the work necessary to further divide the previously comminuted particles. Thus in the one machine is a step or stage reduction from kinetic impact to abrasive rolling. Fortunately the action within the conical mill can be observed by inserting a light at the end of a pole, eliminating theoretical supposition and establishing fact by observation. The proper and most effective speed is one where centrifugal force is neutralized, then overcome by gravity at about 60° from the horizontal. This "proper speed" is again dependent upon the "mesh" of the material fed, for where same is minus 30, impactive action may not be necessary.

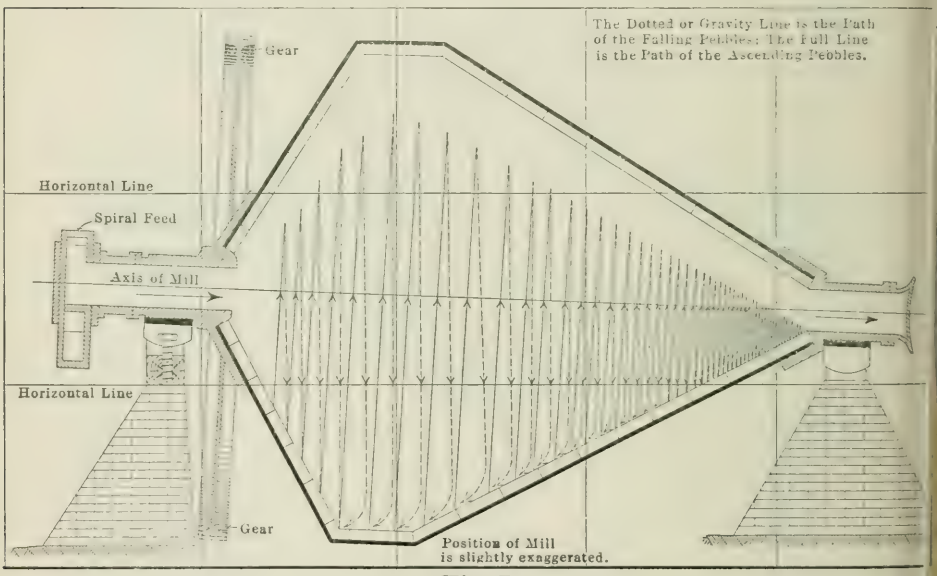

The Dotted or Gravity Line is the Path of the Falling Pebbles; The Full Line is the Path of the Ascending Pebbles.
Gear
Horizontal Line
Spiral Feed
Axis of Mill
Horizontal Line
Gear
Position of Mill is slightly exaggerated.

Fig. 7.

In the case of the conical mill the material undergoing division automatically travels forward at each reduction as though actuated by an Archimedes screw, up and out of the cone, while in the older style of cylindrical mill, of equal dimensions throughout its length, the travel is dependent upon displacement by the feed and the passage through the same varying sizes of pebbles from end to end

Perhaps the main causes for this sizing and step reduction action can be explained by the following diagram, in which it is shown that when the mill is operated on an inclination from the horizontal the charge is lifted at right angles to the axis, but in falling drops, under the action of gravity, vertically and at an angle to the line of lift. The larger particles undergoing disintegration, according to respective mass content, will fall faster than the finer particles which must then, due to displacement, find a position nearer the outlet end of the mill. The material as well as the grinding bodies, through the acceleration due to their mass in falling, reach the lining of mill and continue a course down the cone or inclined surface toward the larger diameter, forming more or less of a triangular line of travel. The finer particles, according to their size and, therefore, friction surface presented, are retarded in their travel down the cone by surface friction and tend to arrange themselves in zones or classified areas. It is to this zigzag action within the mill that the discharge of material as crushed becomes more or less positive and automatic in contradistinction to the action within the cylindrical mill before mentioned. In view of these two cuts it may be readily seen how the two funnels placed base to base may be considered the parent of the standard Conical mill.

A diagrammatic representation of the actual weights of the same number of pebbles, shovelled from four sections of a conical mill, as reported by an engineer who had just finished a test run for efficiency, is shown in preceding Fig. 7.

In dry grinding the most effective peripheral speed is between 625 ft. and 675 ft. per minute, of largest diameter.

The amount of water used in the conical mill should vary with results desired. For fine or slime grinding the best results are obtained with a relation of about 40% of water to 60% of solids, by weight. For coarser or granular grinding greater amounts of water are used to suit conditions and can only be ascertained by experiment.

The following results taken from screen tests covering a period of several days, operating with different amounts of water and inclinations of mill, upon the same (composite) mesh

and weight of feed, will give a fair idea of possible results which may be obtained in the one mill:

	% on	% on	% on	% on	% on	% on	%thru
Mesh	8	20	40	60	80	100	100
Feed	16.7	51.1	13.9	6.8	4.4	3.0	7.0
Tails of 1st test		4.8	9.8	22.8	22.3	0.9	39.0
Tails of 2nd test			1.3	8.0	27.5	2.5	60.0
Tails of 3rd test				1.4	10.0	2.0	87.0

Lining.—The pebble mills are lined with silex blocks throughout or a combination of silex and ribbed steel or iron plates, the plates being fitted with a lifting bar of special design, which not only assists in lifting the mass of pebbles higher, affording greater impact in the central portion of the mill, but also prevents a slipping of the charge.

Conical Ball Mill Compared with Cylindrical Ball Mills.—The older style of ball mill has a peripheral discharge through perforated grinding plates, a coarse protecting screen and a fine outside screen, as shown in accompanying sketch (Fig. 8).

Material not ground sufficiently fine to pass the second or third screen is returned to the mill for regrinding, while the conical ball mill is operated entirely without screens; the sizing and issue being due to the principles involved in the cone, as before mentioned, in referring to this class of mill operating as a pebble mill. The conical mills are equally adapted to operating wet or dry, while the older style of ball mill is operated dry only, except by special provision.

The conical ball mill is lined, as are the other types of ball mill, with steel plates, and various sizes of steel balls are employed to break up the ore or other material undergoing disintegration. Herein comes again the principle of the stage reduction, in that the balls in weight are approximately relative to the size of particle undergoing division, and automatically take positions in the mill relatively to size and diameter of cone. To operate a ball mill of this type to best advantage, the preliminary feed should be reduced by rock crusher so that the largest pieces will not exceed 1½ to 2 inches, or a relative weight to the crushing body of approximately 50:1.

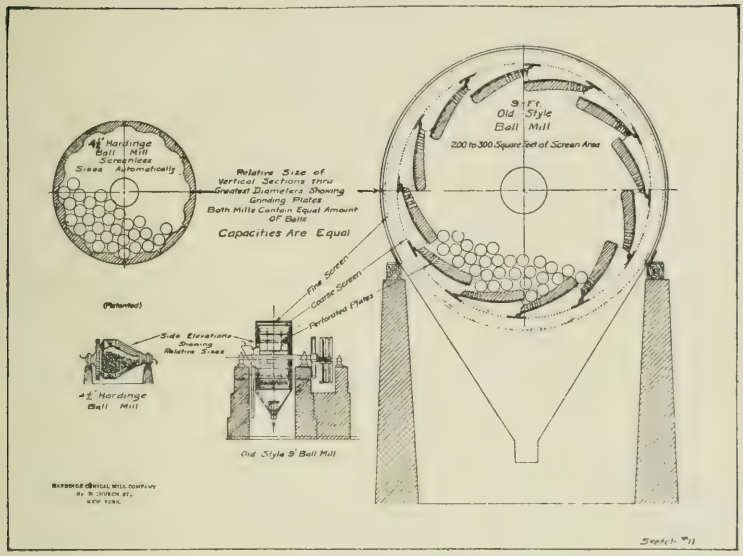

4½' Hardinge Ball Mill Screenless Sizes Automatically
Relative Size of Vertical Sections thru Greatest Diameters Showing Grinding Plates
Both Mills Contain Equal Amount Of Balls
Capacities Are Equal
9' Ft. Old Style Ball Mill
200 to 300 Square Feet of Screen Area
Fine Screen
Coarse Screen
Perforated Plates
(Patented)
Side Elevations Showing Relative Sizes
4½' Hardinge Ball Mill
Old Style 9' Ball Mill
HARDINGE CONICAL MILL COMPANY
No. 9 UNION ST.
NEW YORK
Sketch No. 11

Fig. 8.

The advantage of the conical ball mill over other systems of reduction such as Rolls or Stamps, Chili or Huntington Mills, aside from its extreme simplicity, is in the fact that its principle involves stage or step reduction in a single machine, impossible to obtain in the older form of cylindical mills, whose initial and final energy is the same whether acting upon the 1 inch cube or the 1:64 reduction through division to ¼ inch and smaller particles. The conical mill, however, decreases its energy as the particles decrease in size.

The above sketch shows relative sizes for the same relative capacity in the two styles of the ball mill, as operated in each case by ourselves. The operating and structural simplicity of one over the other is apparent.

THE MIAMI MINE AND MILL.

By J. Parke Channing, New York.

(Annual Meeting, Toronto, 1912.)

The property of the Miami Copper Company is situated in Gila County, Arizona, about 10 miles due west of Globe, which is a very old mining camp (at least for Arizona). The discovery of the Miami Mine is a relatively recent one, ore having been "struck" there in 1907.

The country is a mica schist and gneiss, locally known as Pinal schist, which in character is very similar to the Archean schists that are found in the United States and Canada. Next, south of this schist is a granite, known locally as Schultze granite, and the general contact between the two rocks is east and west. That portion of the Pinal schist which is close to the Schultze granite has been intensely silicified and at the same time has had introduced into it copper-bearing iron pyrites. By the well-known process of secondary enrichment the upper portion of the ore-bearing zone has been oxidized and leached, and the result is a zone of secondary enrichment varying from 200 feet to possibly 600 feet in thickness.

In the ore itself the silification has been so complete that very little of the original constituents of the rock have been left, and it is almost a white quartz, carrying streaks, veinlets and shots of chalcocite, together with some pyrite. The proven ore-body is in shape somewhat like a twin mountain peak, the base being about 1,200 feet by 900 feet, and one peak being somewhat higher than the other.

The ore was first encountered in the exploratory shaft, which, curiously enough, came down on the very tip of the higher peak. The ore, occurring as it does, in this double-peak form leaves a valley, as it were, which is filled with leached capping.

The mine has been opened up from the original or discovery shaft with an idea of having main levels about 150 feet apart, and with sub-levels 25 feet apart. The ore was encountered in this shaft at a depth of 220 feet, and the first extraction level is at 420 feet, the second being at 570 feet. In order to mine the ore a large four-compartment shaft was sunk off to one side of the ore-body, in a zone where no ore was expected, and cross-cuts have been driven from this shaft to the ore, the distance on the 420-foot level being approximately 700 feet and at the 570-foot level 500 feet.

In mining the ore it is planned to take off the outer upper surface of the ore-body with light square sets or slicing, so as to break down the capping; and the main portion of the ore-body below will be worked either on a slicing system or else by means of shrinkage stopes. Inasmuch as every mine requires a different method, considerable leeway has been allowed as to what the ultimate method of extraction shall be. In one portion of the mine a series of shrinkage stopes have been laid out, in which the stopes are 50 feet wide and 600 feet long, and between them are left 50 feet pillars. These pillars, however, have raises in them and lateral cross-cuts reaching into the rooms, so that the men in breaking the ore in the shrinkage stopes work from the various cross-cuts that are in the pillars. The shrinkage stopes are left full of broken ore, and it is planned to slice down the pillars after the rooms are completely broken and are ready to be drawn, and to regulate this drawing so that it keeps pace with the slicing. Preparatory to this the whole of the top of the ore above, both the broken ore in the shrinkage stopes and the unbroken ore in the pillars, will be taken out by square sets, so as to form a mat of timber. The main tramming level is a gridiron, having drifts 50 feet apart, with occasional cross-connections, the main gridiron being a rectangle 450 feet by 500 feet. At the corner of this rectangle the main cross-cut to the shaft enters.

The ore is dumped down the various raises into shoots, where it is loaded into gable-bottom cars which hold from 2½ to 3 tons. These are hauled by electric locomotives in trains to the shaft, where they are dumped into a pocket which holds about 700 tons. At the lower end of this pocket there are the usual

measuring boxes from which the 7½-ton skips are loaded and hoisted in balance to a bin at the head-frame. The bin holds 1,000 tons. The hoisting of the skips is done by a Nordberg-geared, double-drum hoist. The cylinders are 20 inches and 20 inches by 48-inch stroke, the drums are 10 feet in diameter, and the gear ratio is three to one. The engine is provided with a governor and runs at 75 revolutions maximum speed, thus giving approximately 750 feet of rope speed for the skips. The engine house to the rear of the shaft contains another smaller single-drum Nordberg-geared hoist, which operates a cage in the shaft used for raising and lowering men and timber, there being two ropes on the same drum, one being attached to the cage and the other to a counterweight which goes down the fourth compartment of the shaft.

The peculiarity about these hoisting engines is that they are both run with reheated compressed air. Quite a large air receiver is placed outside the building, and from this the air is conducted to a Foster air heater, made by the Power Specialty Co. of New York City. This heater is somewhat along the lines of the Foster superheater. It is fired with fuel oil and there is no difficulty in keeping the air at from 400° F. to 450° F. It was originally thought that heated air would have to be stored, but the superheater stores heat in the cast-iron rings around the pipes, and so is quite ready to give out the heat when the sudden demand for air comes from the hoist.

Accurate figures of air consumption and efficiency are not at the present available, other than the knowledge that one cubic foot of reheated air will do as much as two cubic feet of cold air. The engine is handled with great ease, and the advantage of this type of installation is that when the contingency arises, the hoisting engine can be operated with steam, without any change in valves or mechanism. Probably the final efficiency tests will show that 40 per cent. of the power used to generate compressed air will be returned in effective shaft horse power, or tons of ore raised feet.

After the ore enters the bin at the top of the shaft house it is divided into two parts and is fed out by two horizontal rotating cylindrical ore feeders into two No. 7½ gyratory crush-

ers, which are set to reduce the ore to two-inch cubes. The ore then goes to two 4-ft. by 10-ft. trommels provided with ¾-in. diameter holes, the under-size dropping directly down to a conveying belt. The over-size goes into two shaking feeders and is fed into two 24-in. by 54-in. spring rolls, reducing the ore to ¾-in. cubes. The product from these rolls, without any screening, joins the under-size from the trommels and goes to the inclined No. 1 belt conveyer, which is 30 inches wide, runs at 300 feet per minute and has an incline upwards of about 16°. This inclined conveyor runs over a weighing machine, so that the total product passing over it can be determined. This No. 1 conveyer carries the ore to the top of the sampling mill, where a Snyder sampler cuts out one-tenth, the balance going to the No. 2 belt conveyor. The one-tenth sample is then cut successively by four more samplers, each taking one-tenth of the previous sample. The reject from these parts is then elevated and joins the main product on conveyer belt No. 2. The sampling mill has, of course, the usual rolls and mixers, so as to prepare a proper product for successive reduction in size.

No. 2 belt conveyer is a horizontal one, running along the rear of the mill and on top of six steel cylindrical bins, each containing 1,000 tons, and each being behind its own section in the mill. A movable tripper on this No. 2 belt conveyer is so arranged that each bin may be filled as desired.

The mill as laid out comprises nine sections, of which the foundations and concrete base were built, but only six of the sections have been completed and machinery installed therein. A description of one of these sections will give a good idea of the method of treatment.

Under each one of the steel bins above mentioned a short inclined conveyer belt, No. 3, 14 inches wide and running 200 feet per minute, conveys the ore from a combined feeder and sampler placed at the bottom of the bin over a weighing machine and into a shaking feeder. By this means the weight and sample of each section is kept independently of the weight and sample of the whole mill. The shaking feeder feeds the ¾-in. material into a 42-in. by 16-in. roll, which at present reduces the

material to about ¼-in. A part of the mill is equipped with rigid rolls and a part of the mill has spring rolls. The extreme hardness of the ore when reduced to this size has demonstrated that it is impossible to use a rigid roll on material of this kind, and therefore the newer rolls, while still 42-in. by 16-in., are made with springs and are unusual as regards massiveness and size of shafts, bearings, rods, etc.

At the present time the rolls are run dry, the water being added at this point and the product divided into two equal portions and run over two sets of Callow screens, they being provided with .026-in. openings. The over-size from the two sets of Callow screens runs to two 6-ft. Chilian mills, which at present are provided with slotted screens, openings .037 in. wide.

The first three sections of the mill are provided with 6-ft. Chilian mills, as above noted; the fourth section started out with two 8-ft. Hardinge pebble mills, which have since been increased to three. The fifth section is provided with three (one a spare) Chilian mills of a different make, and the sixth section is provided with three Hardinge 8-ft. pebble mills, each with a bevel drive. The result of the work of the Hardinge mills has been so successful that it is contemplated to replace the respective pairs of Chili mills in the first three sections with three sets of three each Hardinge 8-ft. pebble mills. The power consumption of the Hardinge mills is somewhat less, the repairs and maintenance are very much less, and the percentage of 200-mesh slime made is considerably lower than that produced by the Chilian mills.

Practically, from the Callow screen down each section is divided into halves, so that a description of one side will be sufficient in order to understand the flow sheet. The under-size from the Callow screens, together with the product from the Chilian or Hardinge mills goes to a dewatering machine or drag classifier, in which a slowly moving, inclined belt with scrapers on the lower side elevates the sand and pulls it over the lip of the box, the fine material flowing over with the excess water. The sand from this classifier is then introduced into a long, tapered launder with ten hydraulic sorting columns equipped

with the Richards' system of hindered settling. Several other systems were tried out, including the Richards' pulsating classifier, but none succeeded as well on Miami ore as the regular Richards' hindered system.

The products from these ten spigots of the classifier run to ten Deister No. 2 sand tables, and the feed, because of the drag classifier, is remarkably free from slime. The sand tables make three products,—concentrate, middling and tailing. The tailing and middling from the upper four tables, through the number is not fixed and varies according to circumstances, drop down into the basement, where they join a similar product from the other half of the section, and are then reground in a 6-ft. Hardinge pebble mill, the product being treated on two No. 2 tables. The concentrate from the main tables goes to the concentrate launder under the mill and the sand tailing, together with those from the retreatment of the coarse sands are sent to the waste launders.

The overflow from the drag classifier or dewatering machine joins the overflow from the end of the ten-spigot hydraulic classifier and continues down to the slime end of the mill. Here, on either side, it runs into an 8-ft. conical tank, which acts as a dewaterer or thickener. The thickened pulp from this tank goes to a mechanical distributor, where it is divided into six equal parts, each one of which is fed upon a Deister No. 3 slime table. The overflow from this 8-ft. settling tank is then, by another mechanical distributor, divided into eight different portions and goes to eight 6-ft. conical tanks. The thickened pulp from each tank goes to its respective Deister No. 3 slime table, there being of course eight of these tables.

The Deister slime table is so arranged that it makes a concentrate, middling and tailing. The concentrate runs to the concentrate launder, and the middling is retreated in the basement of the slime floor upon two No. 3 tables. The slime floor also has upon it two No. 2 sand tables at its upper end, which are used to retreat the unground middling from the upper series of twenty sand tables.

A number of experiments have been and are being conducted with a view to modifying and improving the above flow sheet. In the first place it is proposed in the shaft crusher house to put in a second pair of rolls, so as to insure the product from the shaft crusher house more nearly approaching ½-in. than ¾-in. This will relieve the work on the intermediate 42-in. by 16-in. rolls in each section; and it is also proposed to make the product from the 8-ft. Hardinge mills of somewhat larger size than at present, so as to throw more work upon the 6-ft. Hardinge mill in the basement, and to considerably improve the treatment of this reground material by the use of classifiers, sand tables and slime tables.

Inasmuch as water is scarce and expensive at Miami, as it has to be pumped for a long distance, a good deal of thought has been bestowed upon the reclamation of water. The overflow from the various sets of 6-ft. tanks is caught at the lower end of the mill, pumped up by centrifugal pumps and fed under the 42-in. by 16-in. rolls. This not only saves the use of fresh water, but also gives the small amount of material not settling in the tanks a chance for treatment.

A very large portion of the waste water is settled out in eighty 10-ft. concrete tanks set upon a level below the tailing launder and the clear water returned by means of motor-driven plunger pumps to the main supply tanks.

The tailing from the mill for the first year was run into a gulch below the mill, the sand forming a dam and the water accumulating behind. This water was picked up by centrifugal pumps mounted on a raft and pumped back to the various supply tanks. As the dam in the first gulch has reached its intended height, the sand tailing is now elevated about 75 feet with four-belt bucket elevators, and the launder is being continued over into the adjoining gulches.

It is quite probable that some improved method of dewatering will be adopted and that the final disposition of the sand tailing will be by means of a wire-rope bucket tramway. Mr. H. Kenyon Burch, who designed the mill, has worked out a

scheme of this kind at the mill which he previously designed at Nacozari for the Moctezuma Copper Company.

The concentrate from the mill is gathered in a launder, glass-lined, which passes through a tunnel under the mill and goes out into another gulch. The concentrate is dropped into eight large concrete settling tanks provided with filter bottoms, very similar in construction to an ordinary cyanide tank. Under the bottom of these tanks there runs an endless belt conveyer, and when a tank is filled and drained the plugs are pulled and the material shovelled upon the belt conveyer. This belt conveyor carries the concentrate forward to a house set in a concrete yard, where box cars are spotted and the concentrate loaded into the box cars. The arrangement is such that by no possibility can any concentrate be lost, all water being pumped back again into the mill.

The concentrate, which carries about 35 per cent. copper, is shipped to Cananea, Mexico, where it is treated at the works of the Greene Cananea Copper Co., most of it being treated by the Day process, in which the dried concentrate is forced by compressed air into a converter while the converter is being blown.

The Miami mine and mill are located upon a hill above what is known as Miami Flat. Along this flat runs the main line of the Arizona Eastern Railway, which is a subsidiary of the Southern Pacific. It was concluded that it was better to build the power house down in the flat, convenient to the railway. This makes the handling of oil, which is used as a fuel, very convenient. The mine and mill supplies are conveyed up the hill on an inclined railroad.

The boiler house is of steel and concrete and contains four 600 h.p. water-tube boilers, each provided with Foster superheaters and independent Green economizers. The usual type of steam-operated oil burners are used, and while the boilers are designed for 200 lbs. working pressure and 100° superheat, at present it is only found necessary to carry the steam at 185 lbs. pressure with the corresponding superheat.

Between the boiler house and the power house a re-enforced concrete stack 205 ft. high and 12 ft. in diameter is provided

for the escape of the furnace gases. This stack is made large enough so that in case coal in future shall be used for fuel, it will have sufficient capacity. The boiler house is also arranged that automatic stokers may be installed and a coal handling plant introduced.

The power plant is just above the boiler house, and produces electricity and compressed air. For the production of electricity there are installed three 1,250 k.w. Crocker-Wheeler alternating current generators directly connected to Nordberg four-cylinder triple-expansion horizontal engines of approximately 1,500 h.p. each, the cylinders being 19-in. and 37-in. and 40-in. and 40-in. by 48-in. These generators run at 107 revolutions per minute and produce alternating current of 6,600 volts and 25 cycles. A certain proportion of this current is stepped down in the power plant to 440 volts and used for the purpose of running the pumps which pump the oil from the tank cars to the storage tank, and also for handling the machinery at the concentrate bins. The major portion of the current is conducted up the hill to a transformer station, located beyond the mill and distant approximately 1,700 feet from the power station. Here the current is stepped down to 440 volts and distributed through the mill, shaft crusher house and the hoist engine house.

In the mill proper each of the 42-in. by 16-in. rolls is driven by its own motor, each set of Chilian and Hardinge mills is driven by its own motor, one motor drives the sand floor machinery and another motor drives the slime floor machinery. In the shaft crusher house, a motor is provided for each gyratory crusher and each set of rolls. In the hoist engine house there are two motor generator sets, each in duplicate, one for giving 125-volt direct current for lighting and the other to give 250-volt direct current for operating the electric locomotives underground.

All of the mill motors are of the usual induction type, with the exception of those attached to the plunger pumps of the reclamation plant. These three are synchronous motors, the fourth one being an induction motor connecting with a float on

the supply tank to start and stop it. The synchronous motors help out the power factor of the station.

Returning to the generators, a certain portion of the current is transmitted at its generated pressure, that is, 6,600 volts to the main pumping plant, which is located very nearly four miles down Miami flat at Burch, where it is used in synchronous motors to pump the water up to the mill.

The compressed air in the power plant is generated at 90 lbs. pressure by two Nordberg steam-driven air compressors. These compressors each have a capacity of 4,000 cubic feet of free air a minute. The air end is two-stage with an intercooler, cylinders being 22-in. and 37-in. by 42-in., the steam end being similar to the generating engines, that is, four-cylinder triple-expansion, cylinders being 14-in. and 28-in. and 30-in. and 30-in. by 42-in.

All engines are run condensing and the plant is provided with two Nordberg counter-current flywheel condensers. The vapour cylinders are horizontal, in line with the steam cylinders of the condensers, while the water plungers are under the floor and are operated by means of bell cranks. The water plungers lift up the water from the condenser chamber to a sufficient height, so that it runs by gravity over the large cooling tower beyond the power house. Evaporation in the dry air of Arizona reduces it to a temperature where it is suitable for use again as injection water. It is found that the evaporation in this cooling tower is about equal to the feed water consumption, thus maintaining practically a balance in the cooling tower reservoir. The plant is also provided with the usual feed pumps, feed water heaters, electric auxiliaries, together with a steam exciter, which is used in starting the plant.

The main power house room is spanned with an electric crane capable of lifting the heaviest piece of machinery in the building. The foundations of the engines are built sufficiently high in the air so that the basement of the building practically becomes a floor below the main floor. The result is that all steam and exhaust pipes are easily accesible and are lighted, there being

windows on all sides. This is a most desirable construction as a steam leak, which means waste of money, can be detected instantly.

The air produced by the compressors is carried up the hill in a 14-in. pipe line and, as has been previously stated, is divided at the collar of the shaft, a portion going down the mine for the operation of the air drills and the balance going to the large receivers, from whence it is reheated and used in hoisting.

As an index of power house costs, it may be stated that the cost of producing electricity is 1.1c. per k.w. hour at the switchboard and that air costs 2c. per 1,000 cubic feet.

As has been mentioned the water for the concentrator is pumped from Burch, which is distant about four miles from the mine. At this point Miami flat narrows and a series of driven wells have been sunk, all of which have encountered good flows of water. The water from these wells has been developed by the air lift method, but in the future undoubtedly motor-driven well pumps will be used to pump the water up from the wells to the sump tanks situated back of the pump house. For the present the water supply is derived from the old Dominion mine at Globe, which is pumping about 4,000,000 gallons a day. Of this anywhere from 1,000,000 to 2,000,000 gallons are sent down to Burch by gravity through a 14-in. wooden pipe line. The amount paid the Old Dominion mine for this water helps defray the cost of their pumping and is comparable with what it would cost the Miami to pump its own driven wells.

The Burch pumping station is provided with two Nordberg duplex plunger pumps, which are equipped with grooved driving or flywheels. Each pump when running at 75 revolutions per minute has the capacity to deliver 1,200 gallons of water a minute, against a total head of about 600 feet. Each pump is driven by a 400 h.p. Crocker-Wheeler synchronous motor, the drive being by ten separate ropes. These motors take 6,600-volt alternating current, which is the same as that developed at the

power station, so there is no necessity of step-up or step-down transformers on the line from the power house to the pumps.

A counter shaft runs the length of the building, and can be driven independently by either of the two motors. From this shaft an air compressor is operated for the purpose of pumping the driven wells and also to furnish air for charging the air chambers. While this air is only delivered at 100 lbs. pressure, a small portion of it is compressed up to the necessary 250 lbs. by hydraulic pressure in a long length of 14-in. pipe and used for charging the air chambers. It is very necessary to keep these chambers supplied with the proper amount of compressed air in order to get the pumps to run smoothly, and inasmuch as the source of supply in the storage tanks is higher than the suction, the ordinary snifting valves are not effective.

The water is delivered to the mill through a 14-in. line, the first 10,000 ft. of it being made of quarter-inch-thick steel pipe in 20-ft. lengths, two lengths connected together with an ordinary sleeve coupling, and the 40-ft. lengths having standard steel flanges on their ends, which are bolted. The upper 10,000 feet is 14-in. universal joint cast-iron pipe, which is .856 in. thick. It was originally supposed that this would be strong enough for the lower half of the line, but before beginning operations it was found that it was too weak and it was consequently replaced with the steel line.

As indicative of the mill work, below is given the figures of the concentrator for the month of August, 1911. The net product is given as 95 per cent. of the copper produced in concentrate for the reason that that is the loss allowed according to the smelting and refining contract.

Ore milled, 50,809 tons.
Heading assay, 2.49 per cent.
Tailing assay, .68 per cent.
Concentrate assay, 40.54 per cent.
Copper per ton, 37.73 per cent.
Extraction, 75.76 per cent.
Ration of concentration, 21.50 into 1.

Weight of concentrate, 2,364 tons.
Total copper produced, 1,917,127 pounds.
Refinery product, 95 per cent of above, 1,821,272 pounds.
Total water passed through mill, 106,000,000 gallons.
Amount of water reclaimed, 82 per ct., 88,000,000 gallons.
Total new water used, 18,000,000 gallons.
Total new water per ton of ore, 365 gallons.
Total water per ton of ore, 2,098 gallons.

While six sections of the mill were originally supposed to be only capable of treating 333 tons a day each, it has since developed that they can easily handle 500 tons, so that the mine and mill are now (July, 1912) treating about 3,000 tons of ore per day and producing over 3,000,000 lbs. of copper per month. Indications are that the limit of capacity of the mill has not yet been reached, and probably the only limit will be what the tables can stand. Apparently a very large tonnage of material, if well classified, can be treated on a table.

The cost of copper delivered in New York is a trifle under 9c. a pound, and this includes the rather heavy cost of mining and of slicing off the upper portion of the ore body.

The last annual report of the company, published about the time of the March meeting of the Canadian Mining Institute, showed 18,000,000 tons of ore. Since that time several drill holes have been put down from the 570-ft. level and have encountered ore at a greater depth than was assumed, and no doubt the tonnage at the end of this year will be very materially increased. While Miami is not a steam shovel proposition, still the high grade of the ore more than offsets this.

The above description of the mine is not technical, but it gives one a general idea of the property. Mr. H. Kenyon Burch has in preparation a paper for the American Institute of Mining Engineers, which will go very fully into the technical questions, and it is hoped that Mr. N. O. Lawton, the Mine Superintendent, will also prepare a technical paper upon the methods of mining.

No. 4 shaft and concentrating plant looking east. Miami Copper Company.

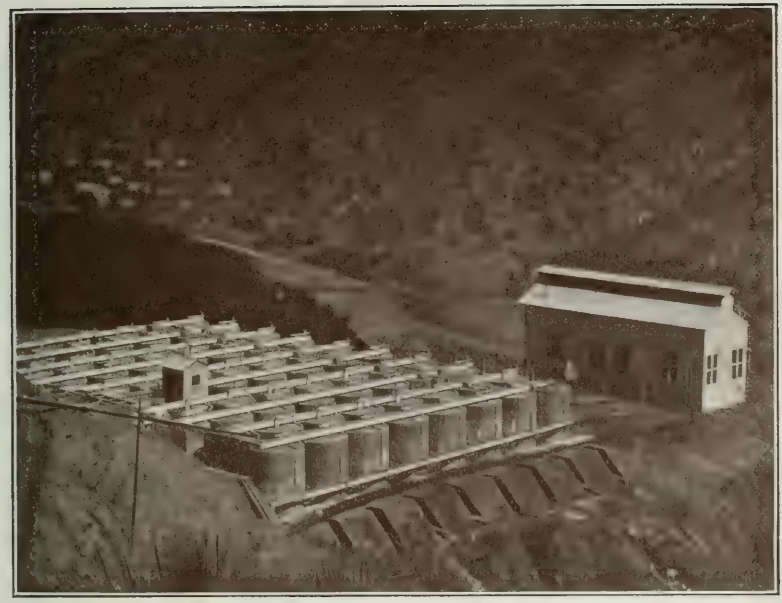
General view, looking south, showing concentrating plant and No. 4 shaft, Miami Copper Company.

No. 4 shaft and concentrating plant, looking north.

Concentrate Tanks.

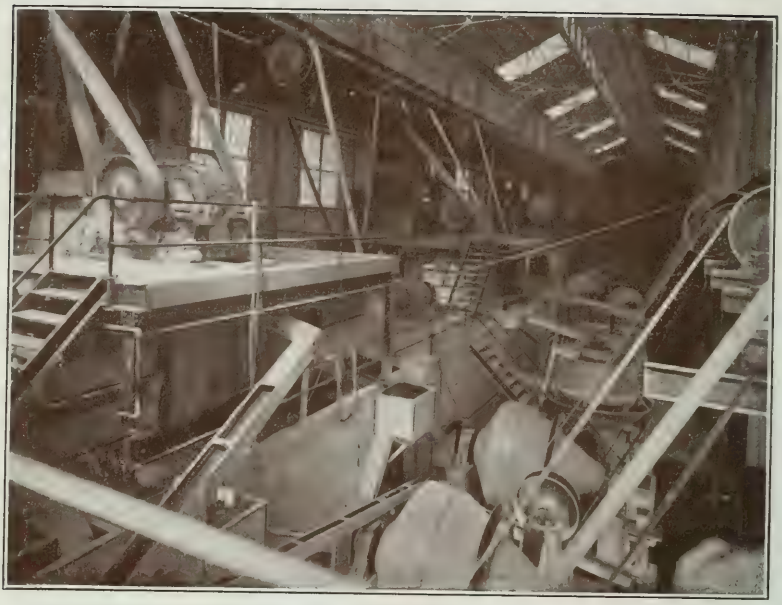
Tailing Dam.

Power House and Inclined Tramway, with mill in background.



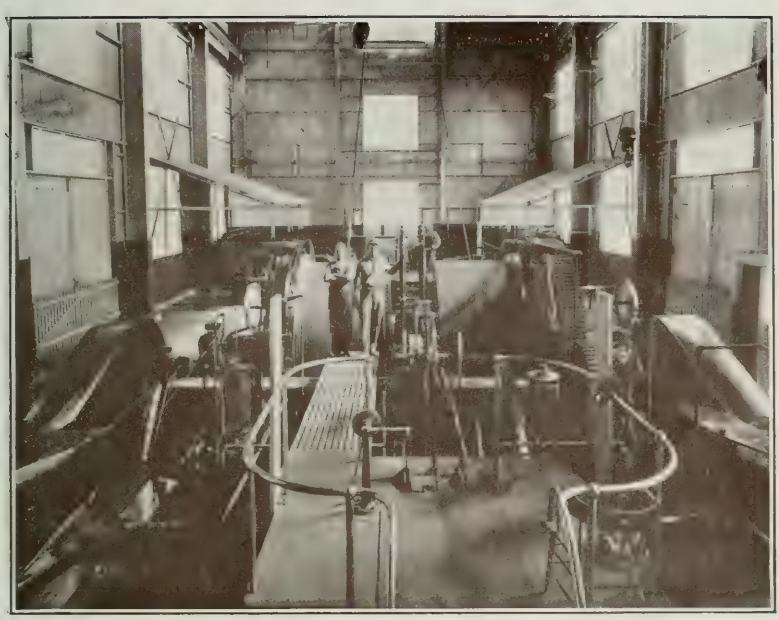
Reclaimed Water Tanks.

Power Plant.

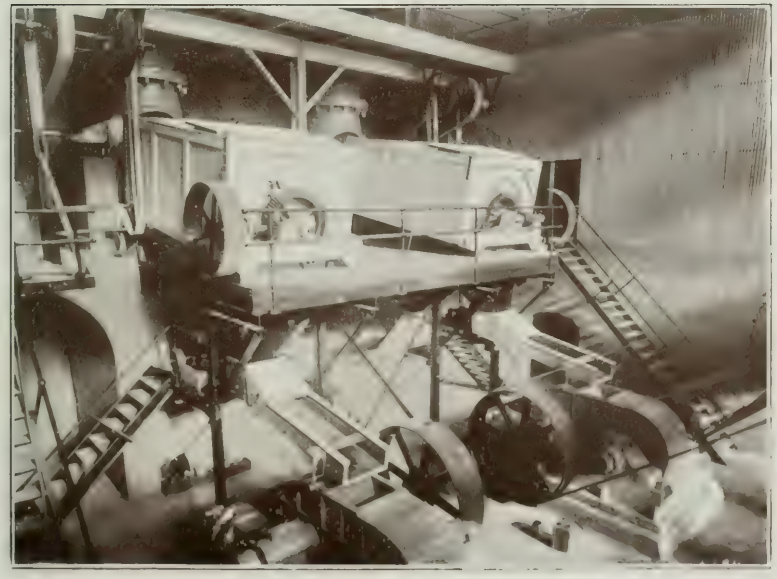


Intermediate rolls and fine crushing machinery.

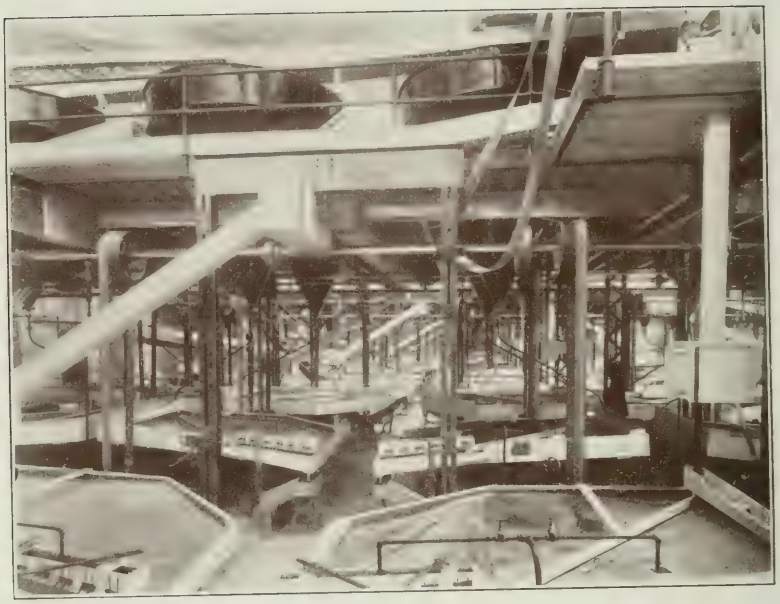
Interior of Hoist House, with the main hoist in the foreground.



Interior view of hoist house, Miami Copper Company.

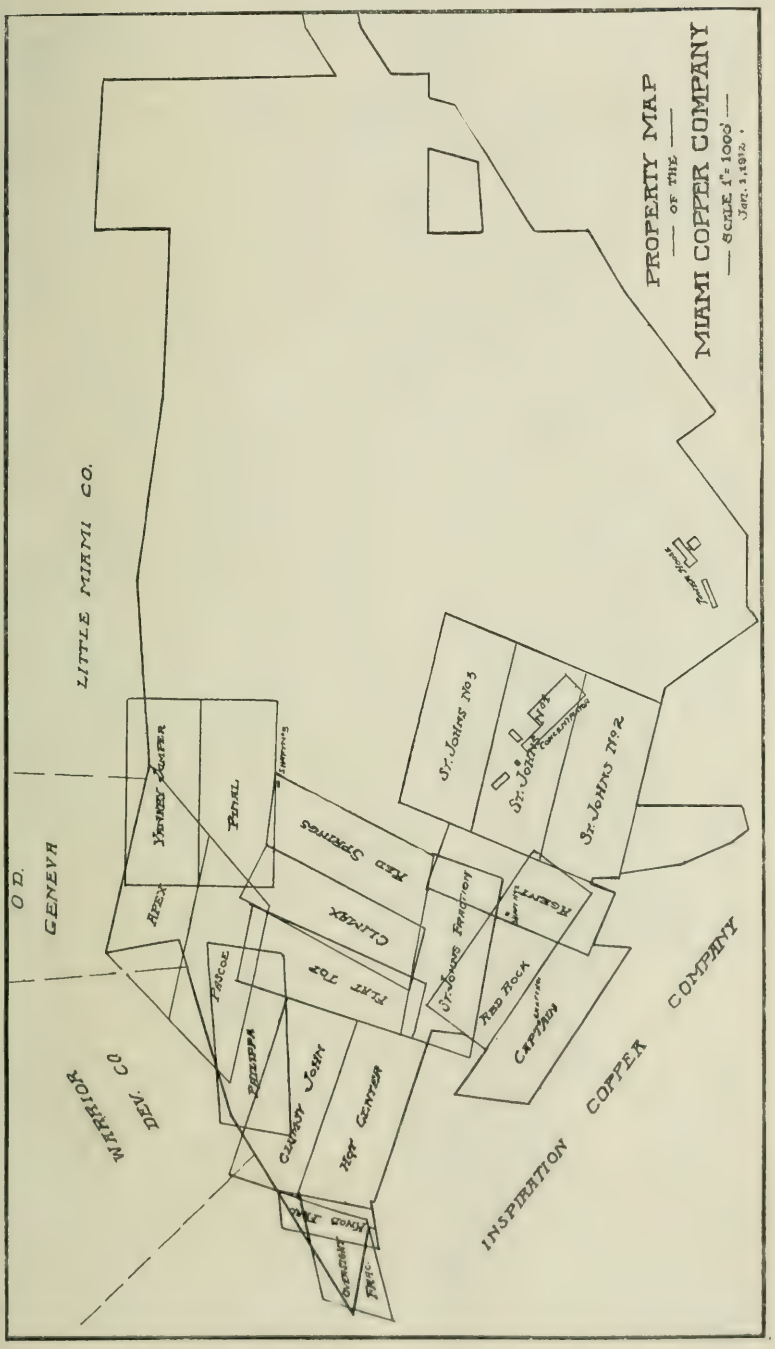


Interior crushing plant, Miami Copper Company.



Slime floor, concentrator, Miami Copper Company.

Sand floor, concentrator, Miami Copper Company.


PROPERTY MAP
— OF THE —
MIAMI COPPER COMPANY
— SCALE 1" = 1000' —
JAN. 1, 1912.
LITTLE MIAMI CO.
O. D.
GENEVA
WARRIOR DEV. CO
INSPIRATION COPPER COMPANY
APEX
YANKEE BOASTER
PENAL
RED SPRINGS
CLIMAX
FLAT TOP
PASCOE
ROSELLA
CANNY JOHN
HOT CENTER
ST. JOHNS FRACTION
RED ROCK
CAPTAIN
ST. JOHNS No 3
ST. JOHNS No 2
ST. JOHN No 1
ROBERT E. LEE
ROBERT E. LEE No 2
ROBERT E. LEE No 3
ROBERT E. LEE No 4
ROBERT E. LEE No 5
ROBERT E. LEE No 6
ROBERT E. LEE No 7
ROBERT E. LEE No 8
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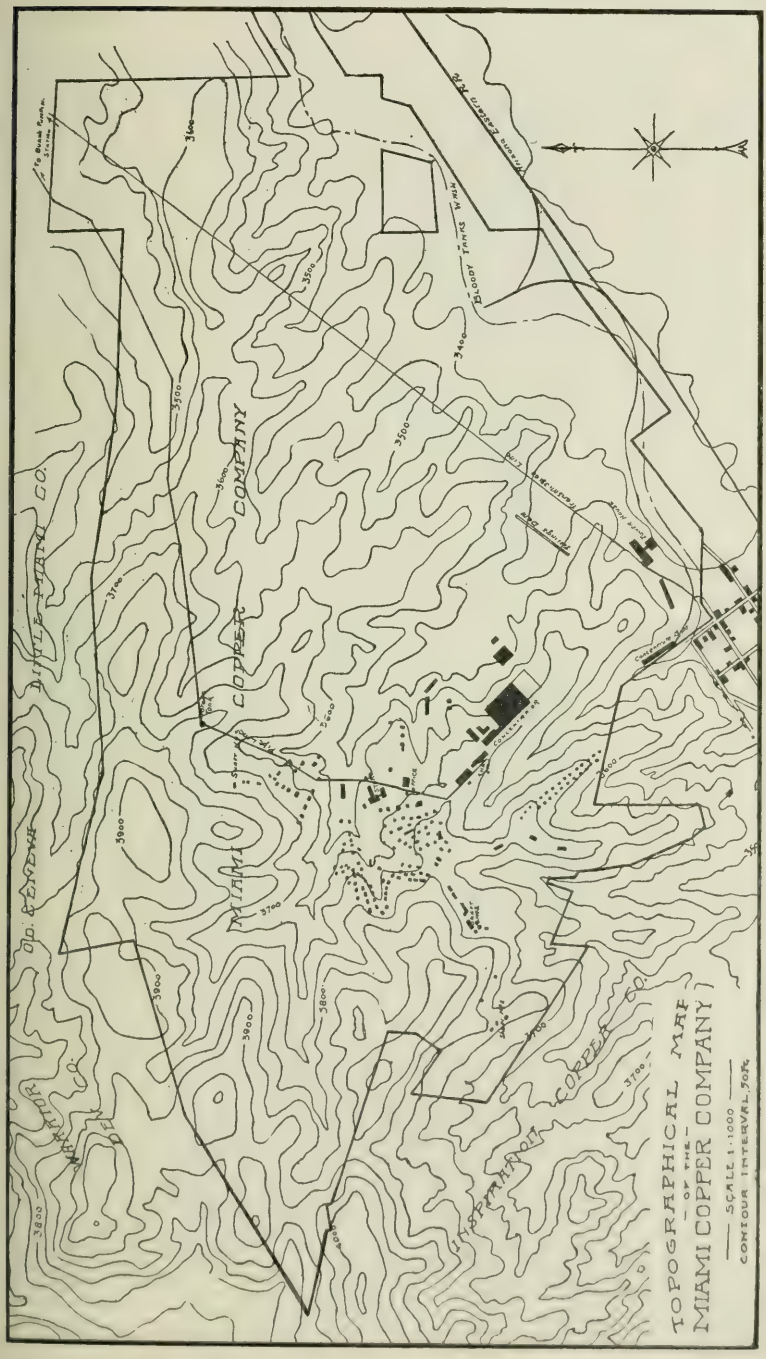
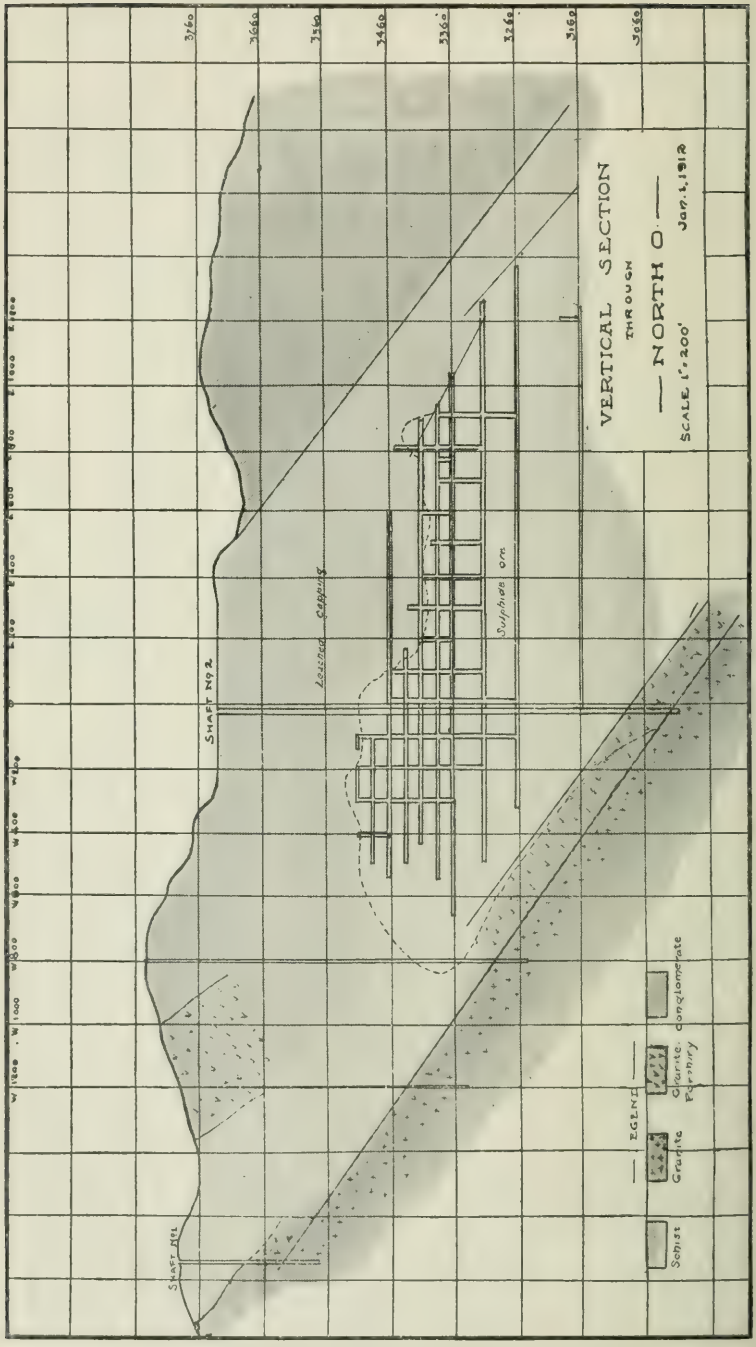
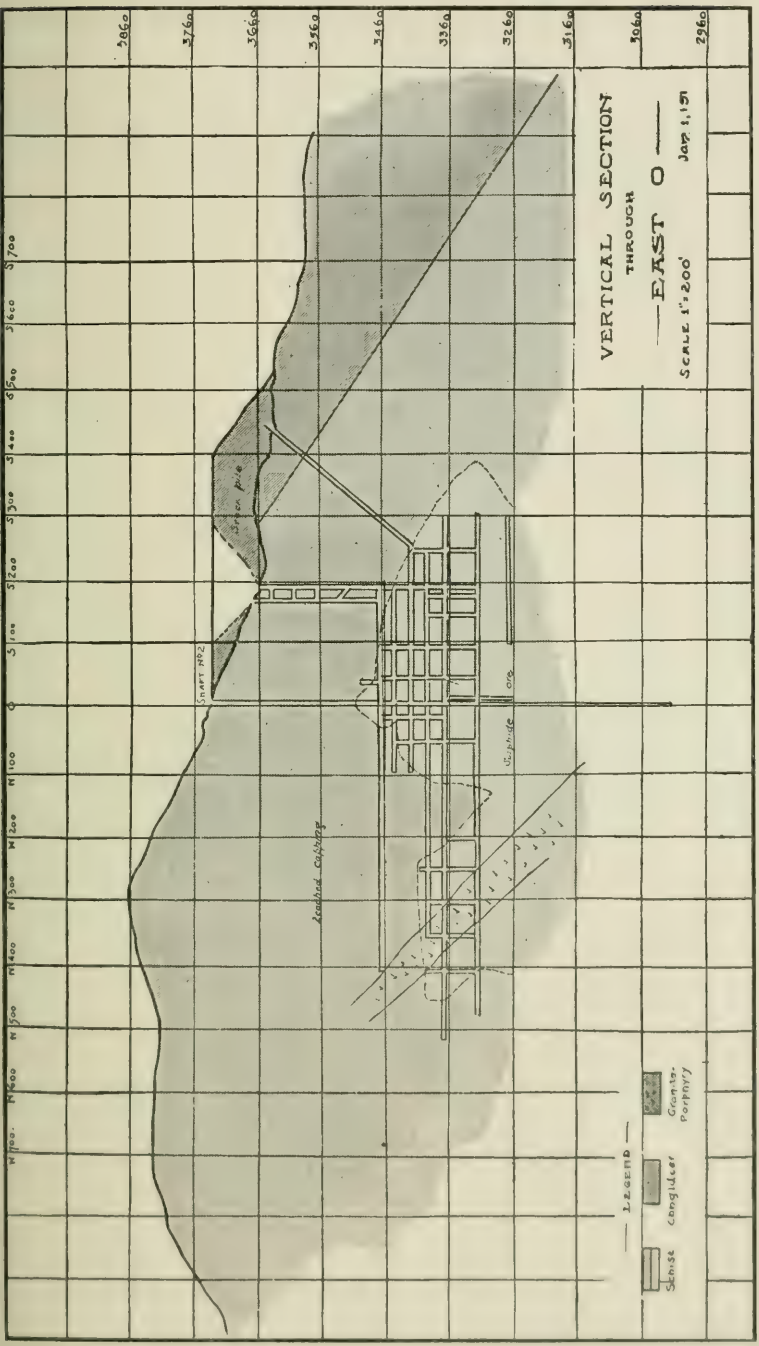
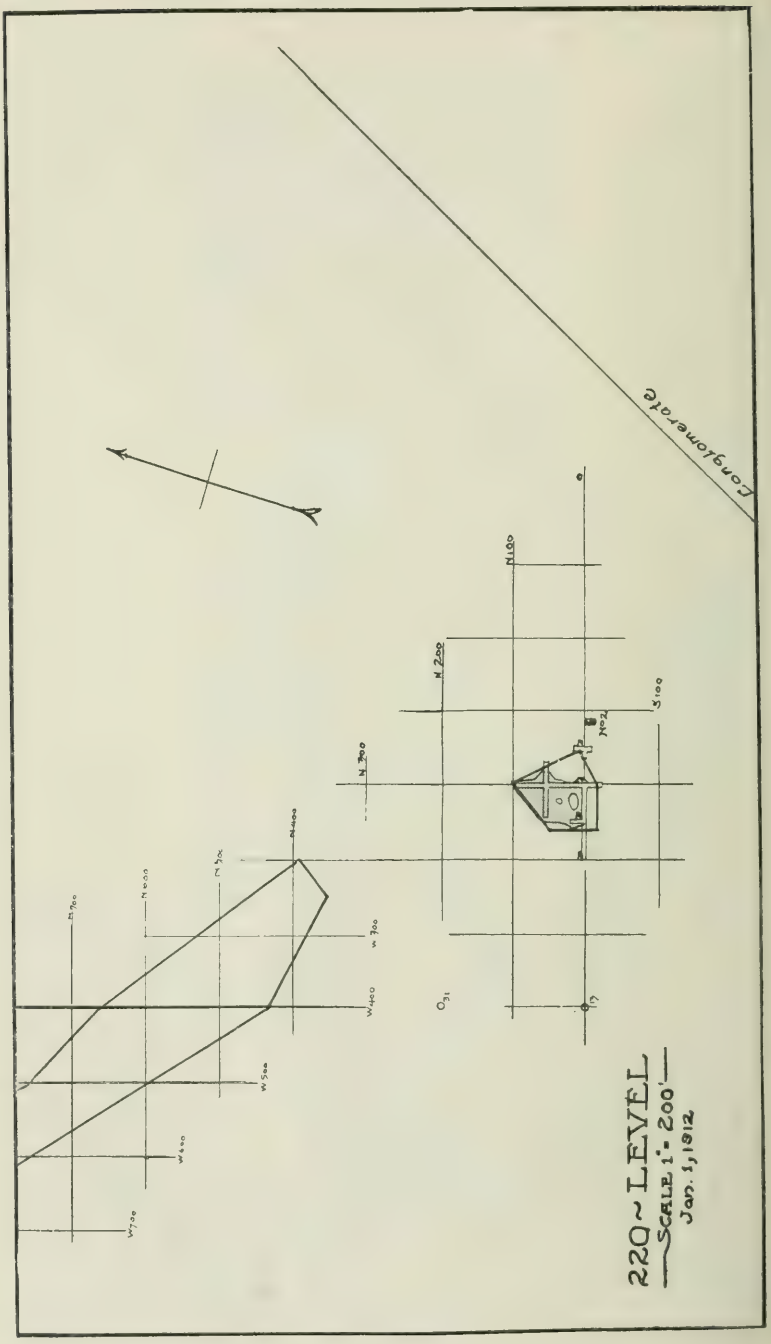
ROBERT E. LEE No 98
ROBERT E. LEE No 99
ROBERT E. LEE No 100

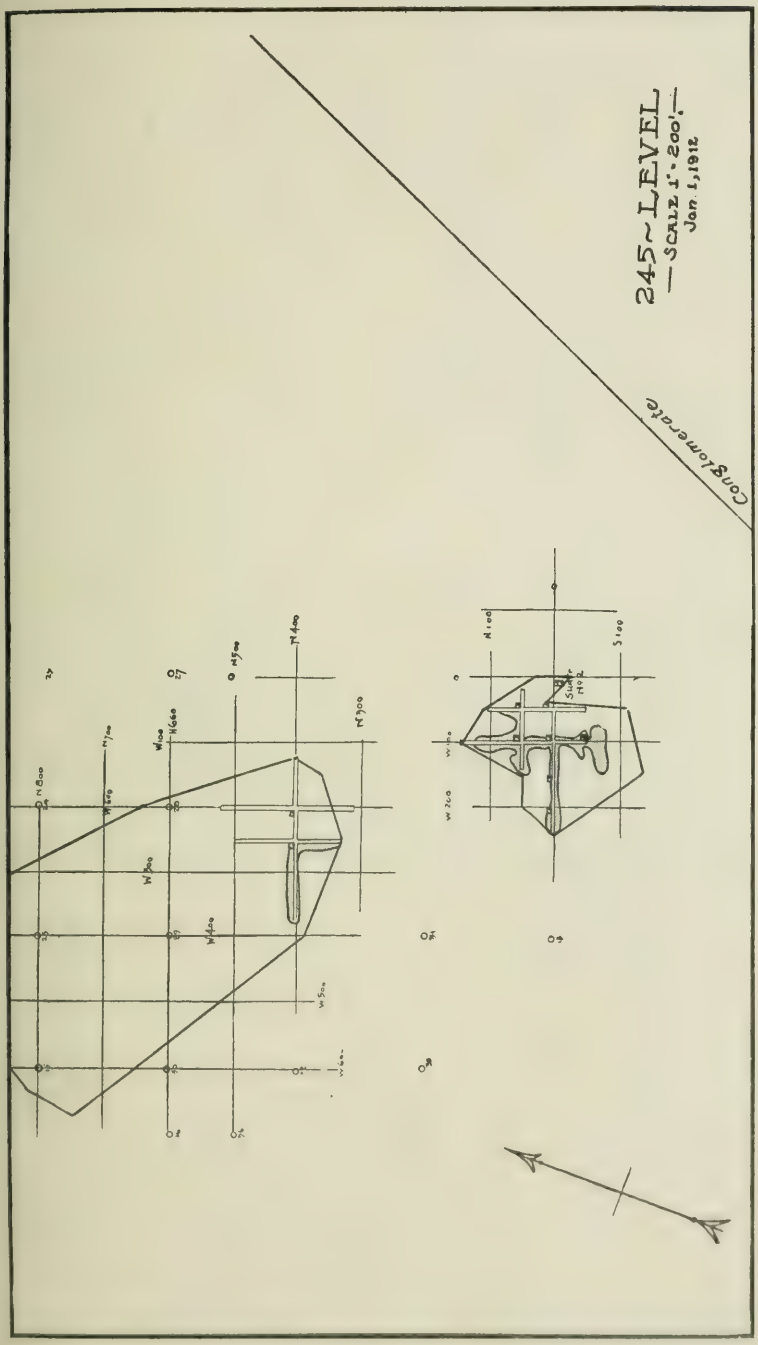
GEOLOGICAL AND
TOPOGRAPHICAL MAP
OF THE
MIAMI COPPER COMPANY
SCALE 1" 1000'
CONTOUR INTERVAL 50'.
LEGEND
Final Joint
Gila Conglomerate
Granite Porphyry
Diorite
Diorite Dike
MIAMI COPPER COMPANY
OLD DOMINION COPPER CO.
MINERAL HILL COPPER CO.
Arizona Eastern R.R.
Bloom Shaft
Miami Shaft
Old Dominion Shaft
Mineral Hill Shaft
Concentrator
Boarding House
Store
Office
Hospital
Powder House
Blacksmith Shop
Engine House
Pump House
Dump
Tramway
Trestle
Road
Creek
Gulch
3800
3900
3700
3600
3500
3400

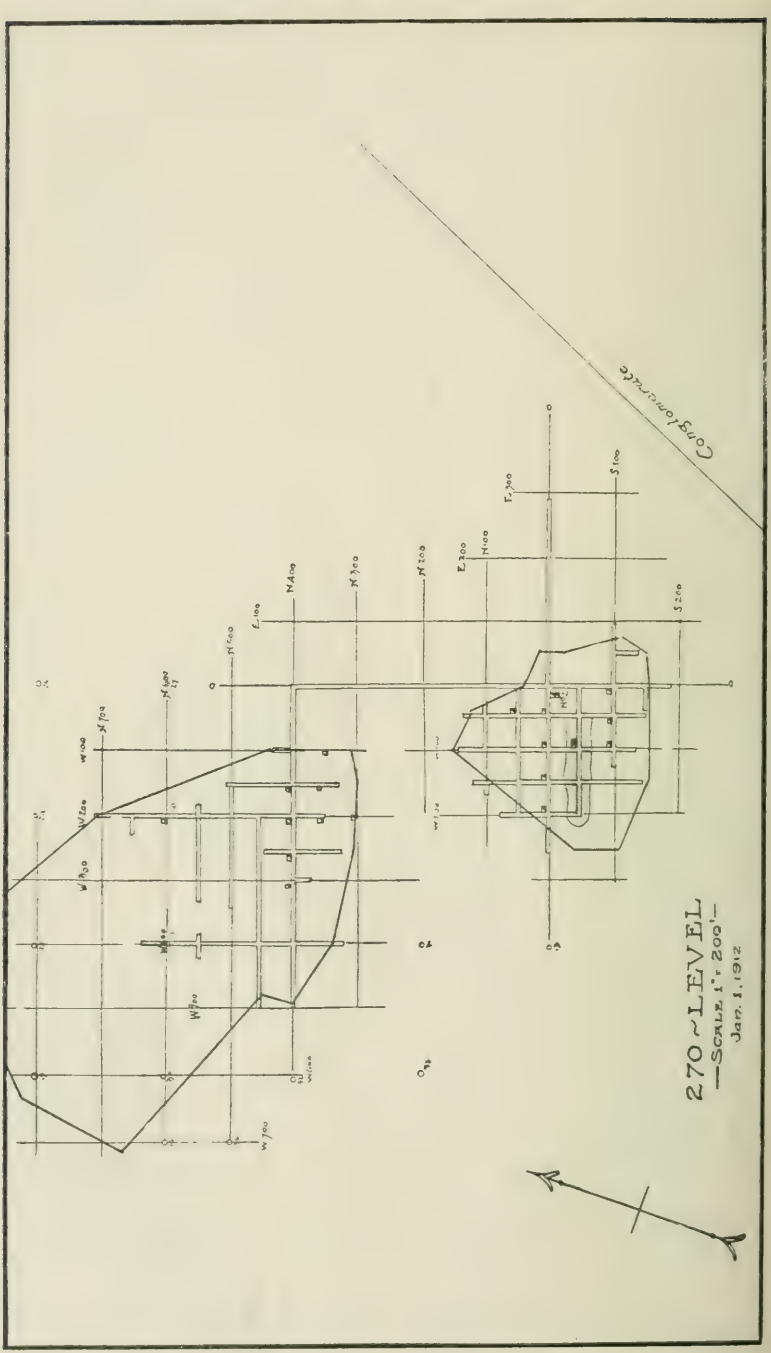

TOPOGRAPHICAL MAP
OF THE
MIAMI COPPER COMPANY'S
SCALE 1:1000
CONTOUR INTERVAL 20FT.
MIAMI COPPER COMPANY
OLD DOMINION CO.
MIAMI COPPER CO.
COPPER CO.
NORTH ROAD
BLOCKS TANKS
3900
3800
3700
3600
3500
3400
3300

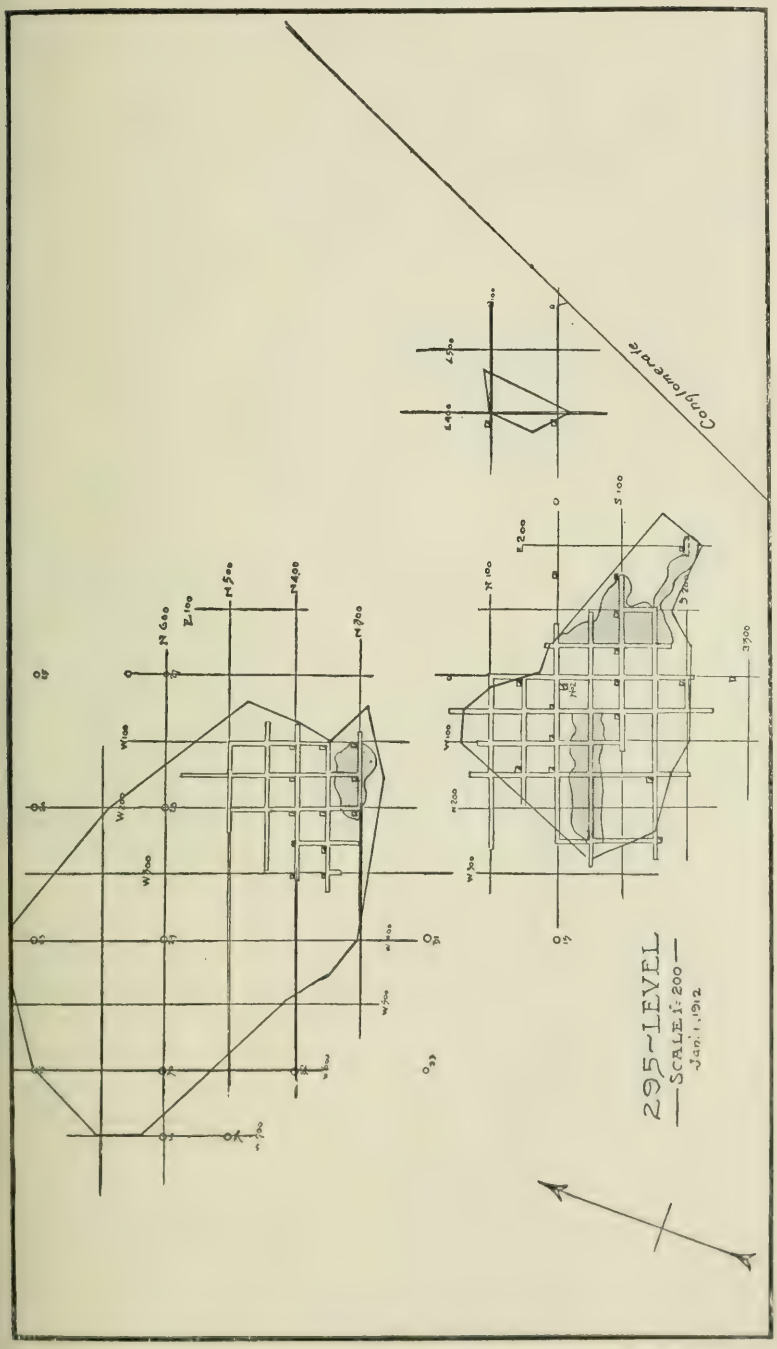

VERTICAL SECTION
THROUGH
— NORTH O —
SCALE 1" = 200'
JAN. 1, 1912
SHAFT NO 2
SHAFT NO 1
Lowest Copper
Sulphides on
Schist
Granite
Granite conglomerate
Porphyry

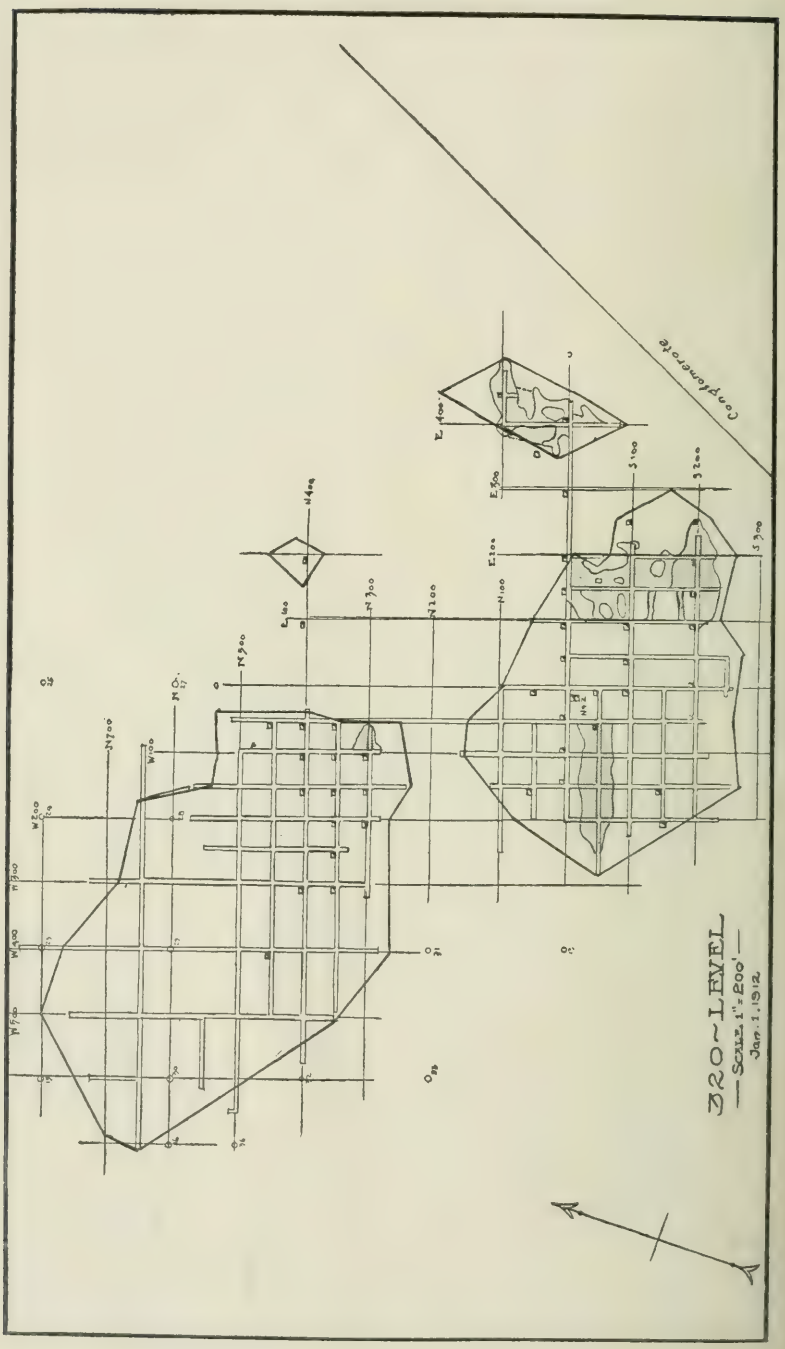

VERTICAL SECTION
THROUGH
—EAST 0 —
SCALE 1"=200'
Jan. 1, 19
— LEGEND —
Schist
Conglom.
Granite-Porphyry
Shaft No 2
Stope pile
Stope
Ore
Footwall Crosscut
3760
3660
3560
3460
3360
3260
3160
3060
2960

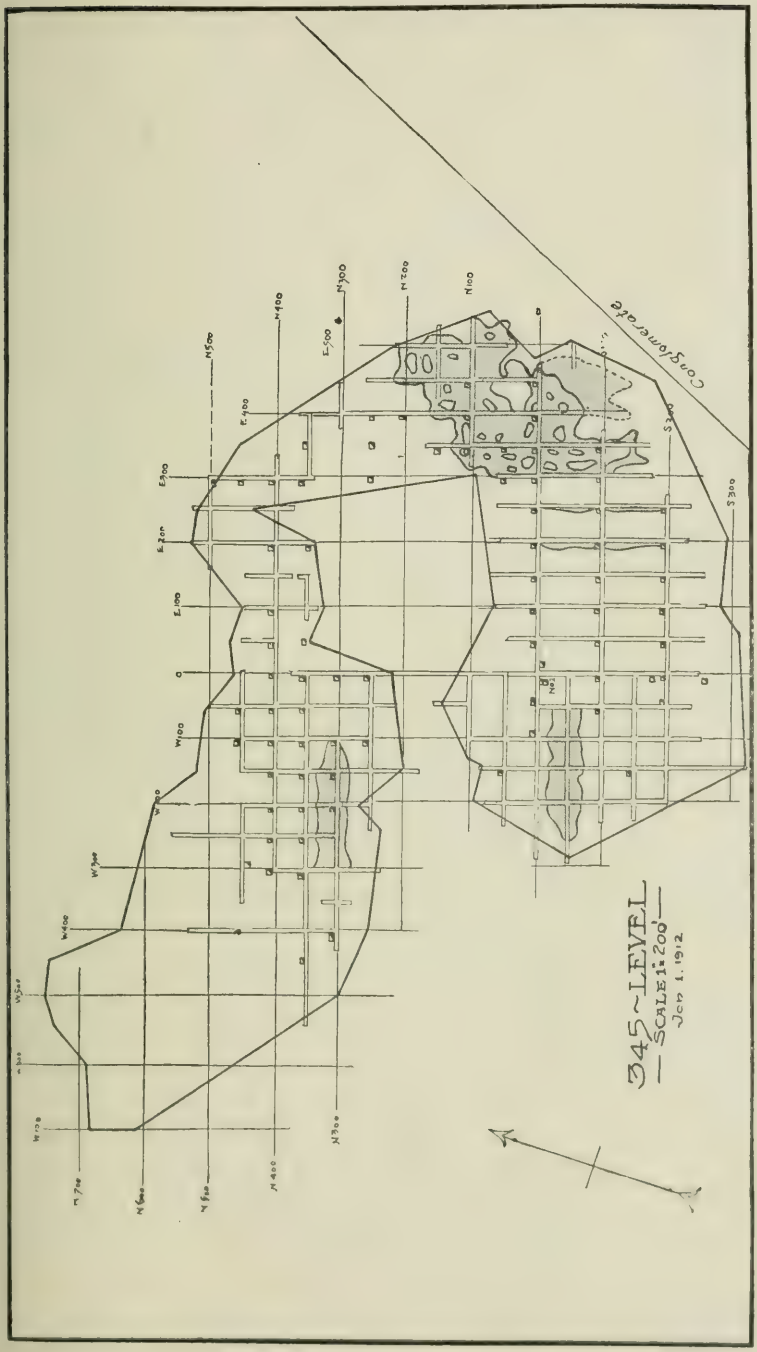

Conglomerate
220 ~ LEVEL
—SCALE 1" = 200'—
JAN. 1, 1912

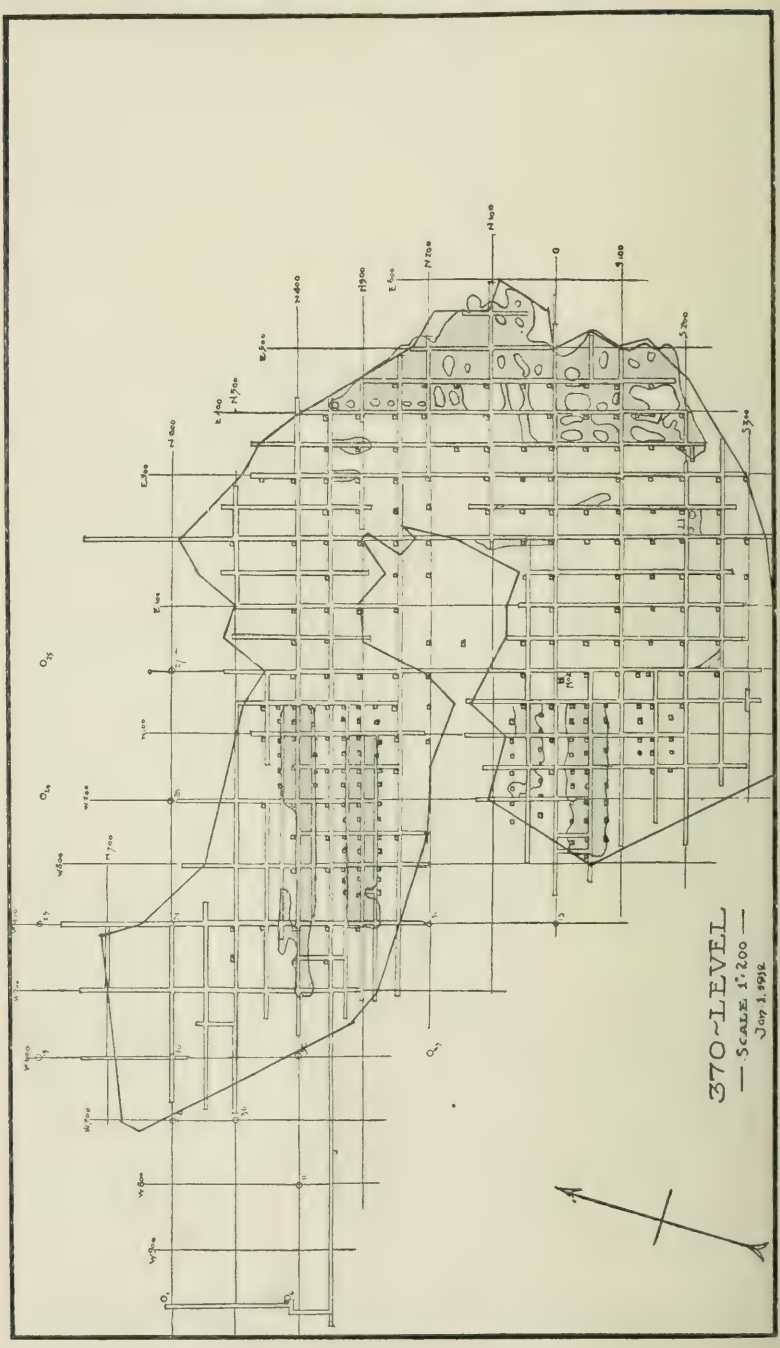

245~LEVEL
— SCALE 1" = 200' —
Jan. 1, 1912
Conglomerate

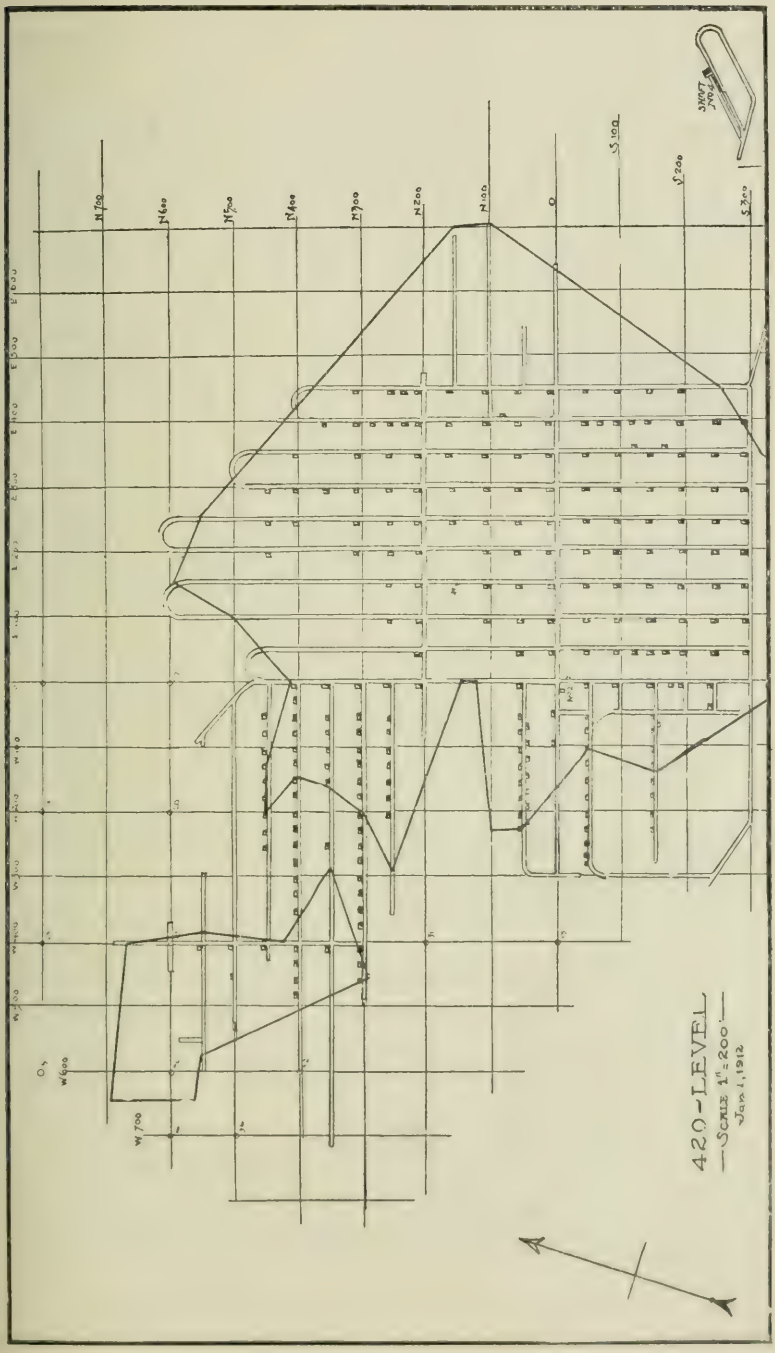

270-LEVEL
—SCALE, 1" = 200'—
JAN. 1, 1912
County Boundary


295-LEVEL
—SCALE 1:200—
Jan. 1, 1912
Conglomerate
N 600
E 100
N 500
N 400
N 300
W 100
W 200
W 300
E 200
N 100
S 100
3900


320-LEVEL
— SCALE 1"=200' —
Jan. 1. 1912
Conglomerate


345 ~ LEVEL
— SCALE 1" = 200' —
JULY 1, 1912
Conglomerate
N100
N200
N300
N400
N500
E500
E400
E300
E200
E100
W100
W200
W300
W400
W500
S300
S200
S100


370-LEVEL
— SCALE 1" 200 —
JAN. 1, 1912


420-LEVEL
—SCALE 1" = 200'—
Jan 1, 1912

THE DEVELOPMENT OF FINE GRINDING IN CONNECTION WITH GOLD ORE TREATMENT.

By Henry Hanson, Porcupine, Ont.

(*Porcupine Meeting, December,* 1911.)

Some years ago the stamp stood practically alone as a fine grinder where wet crushing was employed; but of late years the tube mills and grinding pans have made great inroads upon the former work of the gravity stamp, and to-day the stamp is being relegated to the position of a primary crusher. In the old school, the ore was reduced to a fineness where it would give up its gold to the quicksilver. The subsequent cyanide treatment of the plate tailings, if any, was largely confined to the sands, the slime being avoided instead of sought. The circumstances leading to the first successful attempt at fine grinding on a large scale may be summarized as follows:

A telluride sulphide ore of an uncommon type, rich in gold, did not yield its values by the ordinary method of treatment. Smelting under the conditions obtaining at the time was economically unprofitable, as only the very high grade ore could stand the cost. Experiments with a view of treating the bulk of the lower grade ores of the Kalgoorlie mines were carried on, first by roasting the whole product after crushing, secondly, by wet crushing and concentration, roasting of the concentrates, leaching of the sands and filter-pressing the slimes. The results obtained were in no way satisfactory. At this juncture the London Hamburg Gold Recovery Co., Ltd., had completed the Hannan Brown Hill mill, which was designed for the treatment of oxidized ores, being a dry crushing plant, followed by leaching the sands and filter-pressing the slimes.

Dr. Ludwig Diehl, the metallurgist for the London Hamburg Gold Recovery Co., Ltd., and who had made the Hannan Brown mill a success, was then induced to turn his attention to the treatment of telluride sulphide ores. After a series of ex-

periments, Dr. Diehl determined that by grinding to a fineness not previously attained, the gold could be satisfactorily recovered from the raw ore. The problem then was to find or develop some machine that would satisfactorily and economically reduce the ore to the fineness required. Pans were tried, but did not give the product desired. The tube or pebble mill that was so extensively used by cement manufacturers, was adopted by Dr. Diehl as a fine grinder. The first mill of this type was installed at the Hannan Star mine, Kalgoorlie, by Dr. Diehl. It proved so successful that when the Hannan Brown Hill Co., controlled by Messrs. Bewick-Moreing, reached the telluride sulphide zone, it was decided to erect a stamp mill, employing tube mills as secondary grinders. Since then the tube mill as a fine grinder has been employed in the treatment of gold and silver-bearing ores the world over.

No doubt there are still possibilities for the extension of the scope of the tube mill, but it is impossible to establish any arbitrary rule as to the point to which fine grinding may be carried with economical success.

The additional recovery obtainable by reducing the ore to a fine state of division varies greatly on different ores and on different grades of ores, and it always becomes a question of whether the better percentage of extraction will compensate for the additional cost of reducing the ore to a slime and offset the possible higher treatment cost of a slime product. The relative initial cost of a sand and a slime treatment equipment and the expense entailed in making changes in plants already in commission, must be considered. In fact, it would require a careful weighing of the many phases of the problem by each mine before arriving at a decision in the matter; but as cheaper power is becoming available, and better facilities for handling the slime are offered by the various filters, I am more and more of the opinion that the field for the tube mill will be greatly broadened in the near future.

The tube mill is a simple and efficient machine. The operation of two mills in tandem, each mill of suitable size and design for its particular class of work, the product of the first tube being delivered to a classifier where the fines are thrown out and the

oversize fed to the second mill for further grinding, would appear to be a much simpler arrangement than the provision of different type machines such as rolls or Chilian mills between the stamps and tube mill.

The tube mill has been used very little in cases where a product passing a 35-mesh screen was considered sufficiently fine. Here the stamps have mastered the situation. It may not be economical to use the stamps and tube mills jointly to obtain a 35-mesh product; yet, with the present facility for fine-grinding, experiments along this line should prove valuable. In some instances, I believe, it would be good practice to increase the stamp duty by using coarse screens, regrinding the resulting product in tube mills, even though this made it necessary to put some of the stamps out of commission. Whenever the stamp is followed by the tube mill, more elasticity is obtained, for it is an easy matter to keep a plant in balance and obtain the desired product when a change in the screen practice at the stamps results in a corresponding change in the final product from the tube mill. In other words, when the stamp and tube mill are used jointly it is easy to determine whether the complete sliming of an ore increases the net profits or not. On ore where complete sliming is not economical, it may conceivably be good practice to reduce the ore to a fineness which gives a greater percentage of slime than can be economically obtained in a single stage stamp reduction.

On the Rand, where stamps are followed by tube mills without "all-sliming," the standard of fineness has been raised to 90-mesh instead of 60-mesh as formerly, the additional recovery obtained fully justifying the increased cost of fine grinding. If it was economical to increase the fineness of the final mill product on the Rand, where power is costly when compared with costs in mining districts where water power is available, it is reasonable to suppose that fine-grinding machines have a wide application.

NOTES ON GARNET ZONES ON THE CONTACT OF INTRUSIVE ROCKS AND LIMESTONES.

By J. F. Kemp, New York.

(*Annual Meeting, Toronto,* 1912.)

In the recent discussions regarding the formation of ore deposits the study of contact zones has proved of much interest. These visible products of the influence of igneous rocks on their walls give us a solid ground for observation and interpretation and have, therefore, been peculiarly satisfactory. Yet not all contact zones possess significance. Ores are almost exclusively found in those produced by the action of igneous rocks on limestones. While other contacts, notably those of granites on shales and slates are extremely attractive objects of petrographic study, they seldom, if ever, have ore deposits associated with them.

The contact effects on limestones lead to the production of a series of so-called lime-silicates which are very characteristic. They embrace diopside, garnet, wollastonite, epidote, vesuvianite, tremolite, scapolite, and a few rarer ones. Sometimes one of these appears in great abundance, sometimes another, but on the whole garnet and diopside are the commonest. Garnet is present in such abundance as to lead us often to speak of the zones as garnet zones. Besides the distinctive lime-silicates, much chalcedonic and opaline silica and at times much quartz may be observed. Feldspars do not fail. Magnetite, specular hematite, pyrite and chalcopyrite are the most frequent metallic minerals and copper and a little gold are the commonest metals sought by the miner. We do know, however, of cases involving galena, zinc-blende, arsenopyrite, molybdenite, bismuthinite and some rarer sulphides. The characters of the ores and their associations have been discussed both by W. Lindgren* and W. H. Weed.† The study of contacts of this sort was early undertaken in Norway, in the vicinity of Christiania, where in former years

*W. Lindgren. The character and genesis of certain contact deposits. Trans. Amer. Inst. Min. Eng. 31:226-242. 1902.

†W. H. Weed. Ore deposits near igneous contacts. Idem. 33:715-746. 1903. An earlier shorter paper is in the Eng. and Min. Journal, 74: 513. 1902.

iron ores were mined along them.* The Norwegian cases have been the basis in the last two years of an elaborate monograph by V. M. Goldschmidt,† to whom we owe a most important contribution to our knowledge.

The contacts which have been most frequently studied in recent years have been produced by intrusive masses of Paleozoic, Mesozoic or Tertiary age; but there are many instances in the pre-Cambrian areas of very ancient granites or other eruptives, which have developed minerals in limestones. There seem to be some contrasts in the results. Garnet is less common in the very ancient ones, although not unknown, but micas, tourmaline, feldspars, scapolite, chrondrodite, and spinel are prominent and zinc-blende and iron ores are somewhat more in evidence. The famous old mineral localities in the Adirondacks and the neighbouring parts of Ontario are of this character. Others appear in Finland and Sweden. A very thorough study of those in Finland has just appeared and affords a basis for many interesting comparisons.°

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*Lindgren, in the reference just mentioned, cites J. H. L. Vogt, Udsight over det sydlige Norges. Geologi, 1879. They are reviewed in detail in the paper by Goldschmidt, next mentioned.

†V. M. Goldschmidt. Die Kontaktmetamorphose im Kristianiagebiet. pp. 483, figs. 84.

°P. P. Sustschinsky. Beiträge zur Kenntnis der Kontakte von Tiefengesteinen mit Kalksteinen im süd-westlichen Finnland. (Contributions to our knowledge of the contacts of intrusive rocks on limestones in Southwestern Finland.) As printed the paper is in Russian, with a summary at the close in German. Travaux de la Société Impériale des Naturalistes de St. Pétersbourg, 36 : part 5. 1912.

On p. 301, Professor Sustschinsky gives the statistics of the occurrence of fifteen minerals from twenty-three localities, of which fifteen are in Finland and eight near Passau, on the Danube, in Eastern Bavaria. The figures afford an idea of the relative frequency of these minerals in this series of cases. Salite is practically what has been called diopside in the present paper.

Salite, 15 times.	Garnet, 4 times.
Olivine, 7 times.	Epidote, 4 times.
Apatite, 7 times.	Wollastonite, 4 times.
Scapolite, 6 times.	Phlogopite, 4 times.
Titanite, 6 times.	Spinel, 2 times.
Actinolite, 6 times.	Periclase, 2 times.
Chondrodite, 6 times.	Fluorite, 2 times.
Vesuvianite, 5 times.	

These figures will strengthen in the mind of an observer familiar with the old pre-Cambrian cases in North America, the remark made above, that they show some mineralogical conrasts with the later formed zones.

For many years in such study of the garnet zones as was given to them, the garnet was assumed to be of the variety grossularite, 3 CaO, Al_2O_3, 3 SiO_2, and inasmuch as an aluminous portion was well known to be present in all limestones in greater or less amount because of the clay laid down in the course of sedimentation, the inference was drawn that the garnet resulted from the recrystallization of aluminous phases of the limestones under the influence of the heat and pressure of the neighbouring intrusive. The inference was most natural and the belief was well-nigh universal that the zones resulted solely from the recrystallization of matter in the wall rocks, penetrated by the intrusive mass. If we start with calcite, kaolinite, chert, comminuted quartz and a little siderite or limonite as components of the limestone, then grossularite, diopside, wollastonite, tremolite, scapolite, and varieties of epidote and vesuvianite not specially rich in iron, might result. Limestones of the above composition are not uncommon, especially in the cement rocks. In the development of contact zones it was known that when we follow the contact line, marble is often the only result, whereas only here and there do the silicates appear. The natural inference was that the silicates developed where the limestone was earthy and impure, the marble where it was purer calcite or dolomite.

The numerous discoveries of copper deposits in the garnet zones of the southwestern United States and Mexico led some six or ten years ago to renewed interest in the zones and to study of them. It then seemed difficult to explain the presence of large quantities of pyrite and chalcopyrite, as well as magnetite and specular hematite, if one trusted alone to the recrystallization of matter original with the limestone. Yet it was acutely recognized by Joseph Barrell* that this recrystallization involved the production of very porous rock from the loss of CO_2 and H_2O. The porosity was quantitatively calculated and the point made that these porous rocks would be very natural places for the deposition of ores, were such to be brought in by circulating waters.

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*The physical effects of contact metamorphism. Amer. Journ. Sci. 13: 279-296. 1902.

The next important point was the realization in 1905 that when analyzed the supposed grossularite was only in part the calcium-aluminum-silicate and that the calcium-iron-silicate, andradite, was present in larger amount.* Grossularite and andradite may look exactly alike. Both are brownish-green varieties, so like the colour of common gooseberries, that one readily appreciates how naturally Werner was led in 1808 to select the name grossularite, from *grossularia,* the botanical name of the gooseberry.

When it was realized that the garnets were more largely andradite than grossularite and that limestone practically never contained the necessary amount of iron called for, and when further the garnet rock was found to be often very dense and with relatively few cavities, the argument was developed that both the iron and the silica had come from the intrusive rock, and that where they were fed into the limestone, the garnet zones had developed; where the emissions failed, the result was simply marble. At the time (1905), so far as the writer knew, only a few other analyses had been made of garnets known to be derived from these geological associations, although, of course, the variety andradite had been long recognized since the name was given by J. H. Dana in the fifth edition of his great Treatise on Mineralogy in honour of the Portuguese mineralogist, d'Andrada, who described one in 1800 from Drammen, Norway, under the name "allochroite." Two years earlier than the issue of the Tamaulipas paper one analysis had been published (1903) by G. A. Smith, of a garnet from Chillagoe, North Queensland, as the subsequent tables and the accompanying references will show, and in the same year (1905) two or three were published from Morenci by W. Lindgren. As time has passed, however, an increasing number have become available and it will now be of interest to compile them and to show how uniform is the testimony which they give as to the importance of andradite. Incidentally, it may also be remarked, that Dr. Goldschmidt, in bringing out the earlier analyses of garnets from

*J. F. Kemp. The copper deposits at San Jose, Tamaulipas, Mexico. Amer. Inst. Min. Eng. Bulletin No. 4, 885-912, 1905; Trans. 36:178-203, 1906.

the Christiania region with whose geological associations he was familiar, makes clear that, besides the description by d'Andrada just cited, Vauquelin in 1801 made an analysis not essentially different from our modern results, and Heinrich Rose repeated the analysis in 1808. They also called the variety "allochroite" and, while in the last two citations, the locality is given as Konnerud; Konnerud is the name of a hill with some old mines near the important town, Drammen. Of these analyses the writer was not aware in 1905.

GENERAL REMARKS ON GARNETS.

A few general comments are desirable before taking up the analyses themselves. There are at least five garnet molecules which are recognizable in the zones, viz.:

Andradite, $3CaO$, Fe_2O_3, $3SiO_2$.
Grossularite, $3CaO$, Al_2O_3, $3SiO_2$.
Spessartite, $3MnO$, Al_2O_3, $3SiO_2$.
Almandite, $3FeO$, Al_2O_3, $3SiO_2$.
Pyrope, $3MgO$, Al_2O_3, $3SiO_2$.

There would seem to be no good chemical reason why Fe_2O_3 might not take the place of the Al_2O_3 in the last three and thus give three additional molecules. While the five above listed are the ones employed in the subsequent tabulation, the first two are the ones of paramount importance. Spessartite alone ever reaches figures of two digits, and that but once. Yet when we recast analyses for percentages of the garnet molecule we are at times forced to make assumptions. The difficulty usually arises from the percentages of lime. There are sometimes not enough molecules of lime to satisfy both the Fe_2O_3 and the Al_2O_3 in the garnet molecules.

The silica is almost always sufficient. It becomes necessary to give either the alumina or the ferric iron the preference. In determining the values given below, the preference has been given to the alumina. When it was all cared for an amount of ferric iron was used equivalent to the unused lime. The extra ferric was assumed to have crystallized as specular hematite. For example, if the reader will look at Analyses 12, 16 and 21, it will be seen that the percentages of Fe_2O_3 are so high as to justify

the expectation of more andradite than appears. But the percentages of CaO are so low that there is much too little of the protoxide base to care for all the sesquioxides.*

The three lesser varieties of garnet are not of much importance or significance. Diopside is so common that when the MgO is accompanied by excess of SiO_2 above the requirements of the other garnets, it is quite likely to be in this mineral. FeO and MnO may easily be present in pyroxene, included mechanically in the garnet. With a narrow margin of error our percentages, nevertheless, have much significance.

THE COMPILED ANALYSES.

The table of analyses shows very clearly that we have garnets which are nearly pure andradite and others which are nearly pure grossularite. When the grossularite becomes very rich as in the last analysis, it may well be due to the crystallization of a marly limestone, as suggested for this particular sample by Dr. Goldschmidt. The twenty-fourth analysis is of a garnet from a pipe-like mass within the intrusive rock. When its geological

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*It may be clearer for a reader not accustomed to recasting analyses if the process is more fully explained. If we divide each percentage of an analysis by the molecular weight of the substance, we obtain a series of molecular ratios which are proportional to the numbers of the several molecules present. Thus, if we take Analysis I. of the garnet from Aranzazu, and treat it as follows, the process will be clear.

SiO_2	34.85÷ 60=.581,	or dropping the decimal, 581
Fe_2O_3	29.03÷160=.181,	or dropping the decimal, 181
Al_2O_3	2.19÷102=.021,	or dropping the decimal, 21
CaO	32.90÷ 56=.588,	or dropping the decimal, 588
MnO	.35÷ 72=.005,	or dropping the decimal, 5
FeO	.19÷ 72=.002,	or dropping the decimal, 2
MgO	.12÷ 40=.003,	or dropping the decimal, 3

relations are considered, it is a difficult thing to explain except by the influence of calcareous solutions or vapours upon a still highly heated aluminous eruptive. It should be considered in connection with No. 18, which was based on a sample from the same surroundings. We are led by the contrasts of these two analyses, as well as from Nos. 3, 13 and 14 from Konnerud, Norway, from Nos. 12, 16, 20 and 21 from Elba, and from Nos. 7a and 25 from Mexico, that there is much variability. From the same locality one sample may have little grossularite, and another relatively much. Besides the three cited from Konnerud, Dr. Goldschmidt made two additional determinations of Fe_2O_3 from other samples, respectively 23.68 and 19.90. The known variability of limestones themselves would in part correspond with these differences; while it is also true that from igneous rocks of differing compositions and from different places in the same mass one could hardly expect uniform products. On the whole, the testimony of the analyses, representing as they do many widely separated parts of the world, is so uniform as to convince one of the introduction of iron, silica and smaller percentages of manganese and probably of more or less alumina into the wall rock from the igneous mass.

While garnet has been selected as the basis of this discussion, essentially similar conclusions could be drawn from analyses of pyroxenes.

In pyrope $3MgO, Al_2O_3, 3SiO_2$, 3 magnesias, call for 1 alumina and 3 silicas; in almandite $3FeO, Al_2O_3, 3SiO_2$, 2 ferrous irons call for two-thirds of one (or say for round numbers) one alumina and 2 silicas; in spessartite $3MnO, Al_2O_3, 3SiO_2$, 5 manganous oxides call for one and two-thirds (or, say for round numbers) 2 aluminas and 5 silicas. There remain $17Al_2O_3$ for grossularite, which call for 51 each of CaO and SiO_2. We have left 537 CaO which is little less than 3 times the 181 Fe_2O_3 (or 543), but which is so near as almost to balance. So we take as many Fe_2O_3 as one-third the CaO. In turning back to percents of the varieties of garnet we can work the reverse process, or, as the percentage of the Fe_2O_3 is almost exactly one-third the total in pure andradite (33.1 per cent.), we can multiply the percent. of Fe_2O_3 by three. Similarly, in pure grossularite the percentage of Al_2O_3 (25.37) is almost exactly one-fourth, so that for practical purposes we can multiply the percentage of Al_2O_3 by four.

	*Andrad.	Grossul.	Spess.	Almand.	Pyrope.	SiO_2.	Fe_2O_3	Al_2O_3.	CaO.	MnO.	FeO.	MgO.	Rest.	Locality.
1	92.6	3.00	.86	.48	.43	34.85	29.03	2.19	32.90	.35	.19	.12	.16	Aranzazu, Mexico.
2	89.52	.....	.....	.....	....	35.67	31.67	tra.	31.40	.90	.36	tr.	...	Griserud, Norway.
3	88.74	.....	.....	.....	....	35.67	29.58	....	32.59	.94	.25	...	.47	Konnerud, Norway.
4	87.57	1.60	.63	1.46	2.32	36.74	29.19	1.51	31.41	.29	.69	.69	...	Dognaczka, Banat.
5	87.54	3.26	1.01	.90	....	35.44	29.18	1.26	32.62	.48	.41	...	.55	Grua, Norway.
6	86.36	2.96	.79	.....	....	36.26	32.43	.78	29.67	.27	.32	...	.63	Morenci, Arizona.
7	82.15	4.08	.....	.....	5.4	35.70	26.09	3.45	31.20	.22	...	1.43	2.05	Shimohogi, Japan.
7a	76.83	8.80	.....	.....	....	34.68	25.61	2.20	32.54	.14	1.80	.72	2.30	Matehuala, Mexico.
8	67.62	6.02	.91	.....	....	42.63	31.41	1.53	23.37	.43	.30	...	tr.	Morenci, Arizona.
9	64.62	22.44	.....	.....	3.64	34.22	21.54	6.55	35.52	tr.	...	1.10	.80	Vasko, Banat.
10	63.50	13.50	1.38	14.35	....	34.38	19.99	6.36	31.43	.60	6.24	.07	.615	Kamaishi, Japan.
11	61.10	31.00	.....	.....	....	37.15	19.40	6.98	32.44	...	...	...	4.63	San Jose, Mexico.
12	59.04	15.20	.....	.....	....	37.30	31.30	3.80	26.80	...	...	...	...	Elba, Italy.
13	58.52	9.00	14.40	.....	....	37.00	18.50	5.00	30.00	6.25	...	...	...	Konnerud, Norway.
14	53.80	27.90	.....	.....	....	35.00	17.00	8.00	30.50	3.50	...	...	6.00	Konnerud, Norway.
15	53.40	37.40	1.20	3.50	4.40	36.88	17.54	9.62	31.87	.51	1.62	1.11	.27	Silver Bell, Arizona.
16	52.80	23.20	.....	.....	....	37.70	29.20	5.80	28.10	...	...	...	...	Elba, Italy.
17	45.15	41.16	.....	.....	....	36.29	15.05	10.29	32.85	.18	2.92	.45	1.84	Keene Valley, N.Y.
18	44.16	47.82	.68	2.99	1.31	37.79	15.77	11.97	32.57	.31	1.31	.37	.09	White Knob, Idaho.
19	35.46	53.10	.....	.....	....	40.50	11.10	16.70	31.60	tr.	...	tr.	.30	Chillagoe, N. Queensland.
20	24.90	42.00	.....	.....	....	39.70	17.20	13.10	30.30	...	...	tr.	...	Elba, Italy.
21	24.28	40.80	.....	.....	....	44.50	18.20	10.20	27.00	...	...	...	...	Elba, Italy.
22	23.50	48.40	.....	.....	....	38.90	19.80	12.10	27.70	...	...	1.60	...	Campiglia, Italy.
23	23.12	65.72	.....	.....	....	39.39	7.99	16.79	35.44	...	.33	.19	...	Sata, Norway.
24	21.13	69.26	.....	1.61	1.44	37.07	10.81	17.42	32.77	...	.68	.51	.53	White Knob, Idaho.
25	9.30	60.80	.....	.....	....	36.98	5.00	15.50	34.89	.09	2.04	1.60	3.90	Matehuala, Mexico.
26	1.92	55.08	.....	.....	....	38.73	5.93	18.36	30.99	3.89	.35	tr.	1.32	Harvold, Norway.

1. A. Bergeat, Neues Jahrbuch, Beilage Band, 28:534, 1909.
2. V. M. Goldschmidt, op. cit. 378, 1911.
3. V. M. Goldschmidt, op. cit. 373, 1911.
4. V. M. Goldschmidt, op. cit. 223, 1911; quoting a dissertation by Seebach, Heidelberg, 1906.
5. V. M. Goldschmidt, 371, 1911.
6. W. Lindgren, Professional Paper, 43:134, 1905. U. S. Geol. Surv.
7. T. Wada—Minerals of Japan, 111, as cited by Goldschmidt, 225.

7a. Booth, Garrett and Blair, for Spurr and others, Econ. Geology, Aug. 1912, 468. Total 97.70, CaO in excess for garnet.

8. W. Lindgren, U. S. Geol. Surv., Professional Paper, 43:134, 1905.
9. Bender and Hobein, cited by Goldschmidt from Neues Jahrbuch, 30: 549, 1910.
10. N. Fukuchi, Beiträge zur Mineralogie von Japan, 75-110, 1907, as cited by Goldschmidt, 225.
11. J. F. Kemp, Bull. Amer. Inst. Min. Eng. 4:900, 1905. Trans. do. 36: 192, 1906.
12. Stagi, Boll. Roy. Com. Geol. d'Italia, 1871, 166, as cited by Goldschmidt, 221.
13. H. Rose. Karstens Min. Tabellen, 1808, as cited by Goldschmidt, 374.
14. Vauquelin, 1801, as cited by Goldschmidt, 374.
15. C. A. Stewart, Bull. Amer. Int. Min. Eng., No. 65, 455-505, May, 1912.
16. As under 12.
17. G. S. Rogers, for J. F. Kemp, not hitherto published.
18. J. F. Kemp and C. G. Gunther. Anals. by T. T. Read. Trans. Amer. Inst. Min. Eng. 38:286, 1908.
19. G. A. Smith. Trans. Amer. Inst. Min. Eng. 34:475, 1904.
20. As under 12.
21. As under 12.
22. As under 12.
23. Goldschmidt, 367, 1911.
24. As under 18. Analysis by Cyril Knight.
25. As under 7a. Total 96.10. The CaO is in excess for pure garnet. The FeO, MgO and MnO were assumed to be in included pyroxene, in making the calculation.
26. Goldschmidt, 364, 1911.

THE METHOD OF INTRODUCTION OF THE IRON.

Special interest attaches to the chemical combinations in which the silicon and the iron and perhaps also the aluminum left the igneous rock. In America magmatic waters have generally been regarded as the vehicle. This conclusion was reached because it was believed that the magmas, as they came from the depths, contained hydrogen and oxygen in solution. Often the hydrogen and oxygen were collectively described, especially by Mr. Lindgren as water gas, but it was inferred that under the exalted temperatures prevailing in the molten mass, the two were probably dissociated. As the magma crystallized to anhy-

drous silicates the water or its components were freed and escaped. Silicic acid or some compound of silicon; iron oxide and sulphide; copper and zinc compounds; and sodium chloride went with them.

From the study, especially of the relations of the minerals at White Knob, Idaho, the writer reached the conclusion that aluminum had also migrated with the other bases, presumably as a fluoride analogous to cryolite.

In the investigation of the extensive bodies of magnetite, in the Iron Springs District of Southwestern Utah, C. K. Leith and E. C. Harder favoured the introduction of the iron from the intrusive into the contact zones as ferrous chloride and gave the following reaction*:

$$3FeCl_2+4H_2O=Fe_3O_4=6HCl+H_2+77 \text{ Cal.}$$

As the authors remark, the magnetite could not exist in the presence of free HCl, but with the neutralizing of the acid by limestone its precipitation becomes possible. By the introduction of ferrous chloride, siderite, an associated mineral in the Utah locality becomes a possibility, but Leith and Harder remark, that, had the iron salt been in the ferric form, hematite would have resulted. They also comment on the evident introduction of soda, presumably through the agency of sodium chloride.

J. E. Spurr and G. H. Garrey concluded, after their studies at Velardena, Durange,† that the metals entered the contacts and associated veins in a definite order in the emissions incident to the cooling of the intrusive and that their precipitation marked a certain stage or several stages in a regular succession. These conclusions, as will be more fully reviewed below, have been strongly corroborated by recent detailed studies at Matehuala, in the State of San Luis Potosi.‡ J. E. Spurr had still earlier

*U. S. Geol. Survey Bull. 338: 77. 1908.

†J. E. Spurr and G. H. Garry. Ore deposits of the Velardena district, Mexico. Econom. Geol. 3:688-725. 1908.

‡J. E. Spurr, G. H. Garry and Clarence N. Fenner: Study of a contact metamorphic ore-deposit. The Dolores Mine at Matehuala, S. L. P. Mexico. Econ. Geol. Aug. 1912. 444-484. J. E. Spurr: Theory of ore-deposition, Idem., 485-493.

reached the view, especially from his studies at Silver Peak, Nev., that the phenomena of vein deposition merely marked stages in a continuous process of magmatic differentiation, incident to the consolidation of an intrusive mass of molten rock. In the formation of pegmatites and quartz veins water or water-gas and other mineralizations enter very largely.*

Dr. Goldschmidt, on the other hand, regards the magmatic waters as not necessarily present, but thinks that the iron left the eruptive as iron chloride or fluoride. The haloid compounds of iron are comparatively volatile and would undergo the following reactions when encountering limestone:—

$$2FeCl_3+3CaCO_3=Fe_2O_3+3CaCl_2+3CO_2.$$
$$2FeF_3+3CaCO_3=Fe_2O_3+3CaF_2+3CO_2.$$

Under the first reaction the calcium chloride in whole or in part came to rest in scapolite whose percentages in chlorine have been shown in later years, and which appears in large amounts in some of the Norwegian zones. Under the second reaction fluorite resulted, a very frequent mineral in the Norwegian cases.

Dr. Goldschmidt believes that the zinc-blende of the Norwegian zones was in the original magma as sulphide which in the presence of hydrochloric acid yielded zinc chloride and sulphurated hydrogen. On encountering the limestone, however, the hydrochloric acid was neutralized and zinc-blende was precipitated. Dr. Goldschmidt in this and in the case of the iron compounds significantly compares the limestone to a filter which selected from the out-streaming gases the elements or compounds which we find in the zones; and let others go by. If, in the case of iron, the molecular ratio of the silicon to the iron was such as to be in the oxidized form of SiO_2 :Fe_2O_3 greater than 3 :1; wollastonite (CaO, SiO_2) resulted in addition to andradite ($3CaO$, Fe_2O_3, $3SiO_2$); because of the excess of SiO_2. On the other hand, if the ratio was less than 3:1, specular hematite accompanied andradite because of the excess of iron over the requirements of the andradite molecule.

*J. E. Spurr: A Theory of ore-deposition. Econ. Geol. Dec. 1907, 791; Aug. 1912, 485.

In a careful and detailed study of the garnet zones at the Silver Bell Mines, Arizona,* C. A. Stewart was impressed with the relations of the garnets to the limestone and reached the conclusion that the lime-iron silicate resulted from the permeation of the rock by gases or solutions under great pressure. By eating into the limestone cavities were afforded in which the solutions in the end deposited the silicates as temperatures and pressures fell. The process is contrasted by Dr. Stewart with one by replacement, molecule by molecule.

Additional support to the view that the metals emerge from the cooling and crystallizing magmas as haloid compounds, more especially chlorides, is afforded by the significant studies of Albert Brun, of Geneva, whose recent volume has given renewed interest to the whole problem of magmatic emissions.† Brun's analyses of gases from active fumaroles show a decreasing amount of water or water gas as he approached nearer and nearer the centre of volcanic activity and secured hotter and hotter samples. He finally concluded that water (steam, water gas in whatever way we may describe it) is absent from the volcanic gases, strictly so-called, i.e., those actually associated with outbreaks of lava at temperatures of fusion. Probably, however, the greater number of geologists, as stated by Dr. A. N. Winchell, will be unable to go as far as does Mr. Brun, in ruling out all water, since in the amphiboles and micas which date back to the earlier stages of consolidation, we find it on analysis, and with no evidence of secondary alteration; and since so many previous observers had quite without exception reported it, but Mr. Brun's researches have certainly occasioned sober reflection upon the whole problem.

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*C. A. Stewart. Geology and ore-deposits of the Silver-Bell Mining District, Arizona. Amer. Inst. Min. Eng. Bull. May, 1912, 493. In this connection there is an acute remark by O. Stutzer in the Zeitschrift f. prakt. Geol. Apr. 1909, 149, in the suggestion that the heat of the igneous mass would itself drive off the carbonic acid gas of the neighbouring limestone, leaving it porous and permeable.

†Albert Brun. Recherches sur l'exhalaison volcanique. Geneva, 1911. An excellent summary and critique by A. N. Winchell will be found in Economic Geology, Jan. 1912, 1-14.

In a review of a paper by the writer,* Professor A. C. Lawson† takes issue with the conclusion that the metallic sulphides have been introduced into the zones by the same agents which have produced the zones themselves or that the ores are the necessary result of pneumatolitic processes at all. Dr. Lawson urges that it is essential to eliminate the introduction of them by subsequent circulating waters, possibly not connected with the intrusive mass, before the general interpretation, as hitherto set forth, may be considered established.

To this it may be replied that the well-nigh unanimous consensus of opinion of those who have studied the zones has been that the metallic minerals go along with the others in method of introduction. So strongly have observers been impressed with the facts of their associations that no other conclusion seemed reasonable. Iron, as represented in the oftentimes great bodies of magnetite and specular hematite, as well as in the iron-bearing silicates, is the metal of chief interest and importance. There seems no way to account for it except by emissions. If the associations of the sulphides, pyrite, chalcopyrite, bornite, zinc-blende, molybdenite, galena, bismuthinite and the rarer ones were such as to indicate their simultaneous or antecedent introduction as compared with the magnetite, specular hematite, and iron-bearing silicates, one would have no reason to attribute to the sulphides a different method of introduction. The following successions have been determined:

1. Morenci, Arizona, 1905. W. Lindgren—
    1. Lime-silicates and magnetite—a few sulphides.
    2. Pyrite with copper, zinc-blende, galena—all in veinlets cutting minerals of No. 1.
2. San Jose, Tamaulipas, 1905. J. F. Kemp—
    1. Diopside and garnet.
    2. Magnetite.
    3. Pyrite and chalcopyrite.
3. White Knob, Idaho, 1906. J .F. Kemp and C. G. Gunther—

*J. F. Kemp. Contact Deposits, in the volume "Types of Ore Deposits," published by the Mining and Scientific Press, San Francisco, 1911.
†Mining and Scientific Press. Feb. 3, 1912, 199.

1. Garnet, diopside, vesuvianite, epidote, with minor magnetite, specularite, chalcopyrite and pyrite as inclusions.
2. Chalcopyrite and pyrite.
3. Bornite.
4. Quartz and calcite.

4. Iron Springs, Utah, 1908. C. K. Leith and E. C. Harder—
   1. Magnetite and other oxides, pyrite, amphibole, apatite and garnet.
   2. Diopside.

5. Velardena, Durango, 1908. J. S. Spurr and G. H. Garrey—
   1. Lime silicates, chiefly garnet and pyroxene—minor sulphides.
   2. Sulphides and quartz.
   3. Barren quartz, becoming mixed with carbonates—finally giving way to abundant calcite.

6. White Horse Pass, Yukon, 1909. O. Stutzer—
   1. Pyroxene and rarely magnetite.
   2. Magnetite.
   3. Garnet, minor sulphides, and some quartz.
   4. Amphibole, sulphides and quartz.
   5. Calcite.

7. Berggiesshubel, Saxony, 1909. O. Stutzer—
   1. Magnetite.
   2. Garnet.
   3. Chalcopyrite.

8. Schwarzenberg, Saxony, 1909. O. Stutzer—
   1. Magnetite and apatite.
   2. Pyroxene.
   3. Garnet and some sulphides.
   4. Sulphides and some amphibole—
      (a) Chalcopyrite.
      (b) Zinc-blende.
      (c) Arsenopyrite.
   5. Amphibole.

   In some specimens there was no regular succession discernible.

9. Christiania Region, 1911. V. Goldschmidt—

Referring only to the introduction of the metals. "Oldest of all is the emission of iron compounds; next follow lead, copper and zinc. Bismuth, on the contrary, is at times of early introduction."

10. Silver-Bell, Arizona, 1912. C. A. Stewart—

1. Garnet, wollastonite, diopside, quartz.
2. Pyrite, chalcopyrite, zinc-blende, quartz, galena later than the other sulphides.
3. Quartz.

11. Matehuala, San Luis, Potosi, 1912. By J. E. Spurr, G. H. Garrey and C. N. Fenner—

1. Aluminous pyroxenes.
2. Grossularite and vesuvianite.
3. Wollastonite.
4. Lime-iron pyroxene (hedenbergite).
5. Andradite.
6. Fluorite, quartz, metallic sulphides, actinolite.
7. Metallic sulphides, quartz and fluorite.
8. Calcite.

In general, although not invariably, the formation of the silicates seems to precede that of the magnetite and the sulphides, but they all are believed to belong to one process. The sulphides are irregular in distribution and so far as recorded descriptions go, they do not seem to be associated with faults or other nourishing waterways through which they might have entered after the contact effects had been produced. Despite Professor Lawson's strictures, the general testimony favours essentially pneumatolitic methods.

In the Matehuala instance, the authors strongly support the introduction of alumina, but in the Christiania zones, Dr. Goldschmidt refers all the alumina to the original sediments. Obviously there is some difference of opinion regarding the behaviour of this base. In the Matehuala instance again the authors have traced out the more detailed order of introduction of the ores as

follows: They belong in groups 6 and 7, as given above, and are divisible into the following succession:

(a) Chalcopyrite and pyrite.
(b) Arsenopyrite, slightly auriferous.
(c) Pyrrhotite and pyrite, may or may not be argentiferous.
(d) Zinc-blende.
(e) Galena.

Dr. Goldschmidt has endeavoured to express the relative amounts of the metals which have been supplied by the eruptives to the Norwegian zones. They are in order: (1) Iron; (2) Zinc; (3) Copper; (4) Lead; (5) Manganese; (6) Bismuth; (7) Silver; (8) Molybdenum; (9) Cobalt; (10) Antimony; (11) Beryllium; (12) Cerium. The metalloids or their oxides are arranged in the following order: (1) Silica; (2) Fluorine; (3) Sulphur; (4) Chlorine; (5) Arsenic; (6) Boric Acid; (7) Titanic oxide; (8) Phosphoric acid. These successions are very suggestive and will stimulate the reflections of others in the study of the zones.

DISCUSSION.

MR. W. LINDGREN: I am very much interested in the great mass of cumulative evidence that Professor Kemp has brought forward. When we first establish a theory like this, the evidence is necessarily scant, and I am very glad, indeed, to see how the evidence is accumulating and strengthening on every hand.

DR. T. L. WALKER: Dr. Kemp has not referred to any Canadian examples of this type. We have a splendid typical example in the mines at Marble Bay, on Texada Island, B.C. Here there is an abundance of the marble in question and a notable development of light buff-coloured garnet. The principal copper ore is warrenite that they have been mining for a good many years, and at present they are mining at a considerable depth below sea level.

SUCCESSIVE PHASES OF MINERALIZATION IN VEINS OF VOLCANIC REGIONS.

By Waldemar Lindgren.

(*Annual Meeting, Toronto,* 1912.)

Veins formed near the surface are sometimes subject to peculiar changes which rarely are observed in deposits of more deep-seated origin. An earlier series of gangue minerals, usually sulphates or carbonates, may be wholly wiped out and replaced by a new gangue of quartz, adularia or other minerals. Indications of this process may be seen even where it has not been carried to completion. In many veins of Cripple Creek deposition began by the growth of slender crystals of celestite from the walls, and these crystals were subsequently replaced by quartz in which mineral the pseudomorphs are now embedded. In the Trade Dollar vein at Silver City, Idaho, the filling consists now of quartz and adularia, but casts of barite or calcite covered with minute crystals of adularia indicate that here also there was a preliminary carbonate or sulphate stage.

Replacement by Quartz and Adularia.—In many instances the vein was completely filled by calcite, each grain separated by a slender partition of quartz; at the beginning of the second stage this calcite was dissolved, leaving a skeleton of these slender walls; secondary quartz and often also adularia were deposited upon these, giving them more strength, but the ore remained a delicate aggregate of "hackly" or lamellar quartz, remarkably characteristic of some mining districts. The first place from which such pseudomorphic quartz was described was, I believe, Schneeberg in Saxony. The veins at this place, which carry silver, cobalt and nickel, contain a gangue which now consists of fine-grained, hornstone-like quartz, which gives plain evidence of being pseudomorphic after barite and calcite. No exact information is available as to the depth at which the deposition of these veins took place.

In the Cordilleran region many of the veins of Tertiary age which usually occur in andesite or rhyolite contain gangue of this kind. At De Lamar, Idaho, the ore consists of a delicate cellular mass of quartz lamellae.* In the Black Mountains of Western Mohave County there are a great number of veins in the prevailing volcanic complex, which generally carry gold with few other metals or minerals. The Gold Roads mine is the best known of these deposits, and has in recent years yielded a large production. In all these veins the original gangue material consisted of calcite and fluorite, which minerals have now, to a large extent, been replaced by quartz and adularia. The adularia is seldom developed as large crystals, but commonly intergrown with the fine-grained pseudomorphic quartz, in which it is often embedded as delicate crystals of rhombic form.† Similar ore may be seen in the Annie Laurie mine in the Mount Baldy district in Southern Utah,‡ at Jarbidge, Nevada,° and at many other places. This important development of adularia, involving transportation of alumina by siliceous solutions and the crystallization of a feldspar at the low temperatures at 100° to 200° C., remains without full explanation; at present I am unable to present a satisfactory theory of these occurrences. The composition of the ore may be similar to that of a pegmatite dike, but the structure is wholly different.

In any ore composed of calcite with smaller amounts of quartz, leaching by surface waters would readily produce a structure somewhat similar to that described above. It is probable that this has taken place in the upper levels of the Waihi mine, New Zealand, but here the secondary deposition of quartz and adularia is absent. It occurs, however, in the Talisman and other veins at the adjacent district of Karangahake. It is scarcely conceivable that the deposition of the latter two minerals can have taken place by cold and descending surface

*Twentieth Annual Report, U. S. G. S., Part III, pp. 65-256.

†F. C. Schrader, Mineral Deposits of the Cerbat Range, Black Mountains and Grand Wash Cliffs, Mohave County, Arizona; Bull. 397, U. S. G. S., 1909.

‡Bull. 285, U. S. G. S., 1905, p.

°F. C. Schrader, A Reconnaissance of the Jarbridge, Contact and Elk Mountain Mining Districts, Nevada; Bull. 497, U. S. G. S., 1912.

waters, and where this alteration occurs in typical form it is found to reach to the deepest levels attained in the deposit. I believe it is a safe conclusion that these phenomena of replacement have been caused by a change in the composition of the ascending currents during the latter stages of primary mineralization. Most of these deposits carry gold as the principal metal, and there is some reason to believe that the replacement by quartz and adularia is accompanied by a concentration of the gold content of the earlier veins. This conclusion cannot be regarded, however, as fully established.

Zeolitic Replacement.—Zeolites are foreign to the veins of the deeper zones; in the veins formed near the surface they are occasionally found, but are on the whole rare. At a few places they are reported to occur in the altered country rock. Spurr has described such cases from the Tonopah mining district and Finlayson from the Waihi district. At Guanajuato zeolites are found in the filling of the veins. But in this case they always belong to the latest phases of vein formation. Apophyllite, laumontite and stilbite are the species reported. Few of these occurrences in the vein filling have been carefully studied.

An interesting case came recently under my observation at the Southern Republic mine at Republic, Washington, about twenty miles south of the British Columbia boundary line. The gold-bearing veins at Republic intersect andesites and associated tufts. They are well defined quartz-filled veins, with few visible metallic minerals. The gold is in very fine stage of distribution and can rarely be seen with the naked eye. The quartz is throughout of a chalcedonic character, often delicately banded and very similar to many spring deposits. Replacement by secondary adularia is seldom observed. At the Southern Republic mine, however, there was an earlier deposition of thin tabular calcite, which seems to have been deposited only along the walls of the veins. This calcite is now wholly replaced by quartz and adularia, the replacement faithfully preserving the original texture of the calcite.

In this vein a wholly different replacement was also found. Within a narrow shoot, traceable for a vertical distance of 300

feet, the ordinary banded quartz filling had evidently been dissolved, and a loose aggregate of calcite and laumontite was deposited in its place. The laumontite forms a mass of microscopic crystals, which easily crumbles and justifies the old German name for this mineral species of flour zeolite. The ore in this zeolitic zone or shoot contains mainly silver, whereas elsewhere in the mine gold predominates in the quartz gangue. The silver values often amounted to fifty ounces per ton, but few distinctly recognizable silver minerals could be seen in the ore. It seems desirable to call attention to this discovery for the purpose of ascertaining whether the development of zeolites is not favourable to a silver enrichment. This is probably not the only case of the kind, and similar occurrences should be looked for elsewhere in veins of this class. Many facts from other kinds of veins like those of Kongsberg and Andreasberg indicate that there is some sort of connection between zeolitization and deposition of silver.

In the case described from the Southern Republic mine it is very unlikely that the replacement could have been effected by descending surface waters, for the solution of the quartz, as well as the deposition of the laumontite, would probably require temperatures at least approaching 100° C. For this reason it is believed that the replacement and the silver enrichment took place in the last phases of the primary deposition by ascending waters.

DISCUSSION.

MR. J. PARKE CHANNING: May I ask Mr. Lindgren to dilate somewhat on the Gold Roads, and state if there is any enrichment in the Gold Roads ascribable to descending waters?

MR. LINDGREN: I am afraid I cannot, since I am not sufficiently familiar with the district. I should be inclined to doubt that there is any secondary concentration of gold, except where free chlorine has been generated by reaction between manganese dioxide, sulphuric acid and sodium chloride.

MR. NORMAN FISHER: I was greatly interested in some of the photographic slides Mr. Lindgren has just presented, as they remind me so much of similar occurrences at the Waihi mine, in New Zealand, where I was employed some years ago. I have in my collection some samples of pseudo morphic quartz after calcite, taken from the Martha lode, which are almost identical with those Mr. Lindgren has just shown. Also some showing the laminated and chalcedonic structure, to which he has drawn our attention. In this property a depth of upwards of 1,000 ft. has now been reached, and I understand the quartz is giving way largely to calcite. It is a moot question, causing much discussion of late, whether the quartz has gone finally, or whether this calcite is merely a section of the original vein that has not been replaced by the silicious solutions, and that the quartz will be found to again enter with its attendant values at increased depth. Another similarity to the ore body, described by Mr. Lindgren, is the considerable silver content in the ore and with this the gold is apparently intimately associated. Its proportion to the gold is about six or seven to one, and it occurs mostly as sulphide in streaks and bands, which, by the way, help to show up well the laminated structure of the quartz.

MR LINDGREN: I believe from what I have seen of the Waihi that there has not been much secondary alteration by ascending waters; there is a great deal of calcite there, and there has been some leaching; but I think the leaching of that calcite has been mainly effected by descending waters, because it decreases from the surface quite distinctly. The Waihi also contains a good deal more silver than the mines in which the pseudomorphic replacement has gone on from below, and in which the whole vein material has been replaced. A few years ago when I was there they were very much worried about the calcite, but I understand that in some of those mines very good shoots and large ore bodies have been found in spite of the fact that they had calcite in the veins. In parenthesis I would like to call attention to the fact that the Waihi deposit carries a good deal of selenium in the ores.

DECREASE OF VALUE IN ORE SHOOTS WITH DEPTH.

By F. Lynwood Garrison, Philadelphia, Pa.

(*Annual Meeting, Toronto,* 1912.)

Anyone who has kept in touch with the trend of development in metal-producing and especially precious metal-producing districts, must have noted with interest, if not surprise, the repeated instances of discoveries of ore bodies at relatively deep points in old mines, thus instilling new life to the neighbourhood and affording encouragement to operators of mines similarly situated to explore and extend their deeper levels. In directing attention to this important and interesting subject it must be recognized that one deals with a matter whose inherent difficulties may not be lightly regarded and conclusion may be expressed from which unwarranted deductions might be drawn for promotion purposes or to deceive. It is, therefore, but proper to state at the outset that payable ore deposits do not usually persist in great depth, in fact in a geologic sense they are essentially superficial phenomena. It is true mineralized fissures are known to extend to depths of 6,000 feet and probably much more, but it seems likely they will seldom be sufficiently rich to pay.

The class of ore deposits contemplated in this paper are those in fissures that traverse crystalline rocks, or sedimentary rocks, intimately connected with rocks of a magmatic origin. These associations are almost invariably cut by intrusive dikes or sills of igneous rocks belonging to a subsequent period. The mineralization of these fissures in the process of creating veins was later than the formation of the country rock, in other words the ore deposits here considered are epigenetic. Such fissures, when single, are termed a vein, and when grouped or bunched in a zone or belt may be considered a lode. Of course a lode may be a single vein or no vein at all, but simply an accumulation of ore. It is recognized that the common use of the terms "vein" and "lode" is not altogether satisfactory, but it is not intended

to suggest any rule for their application, further than as a matter of convenience within the limits of this paper. As a general fact, openings or fractures in the earth's crust decrease in size as depth is attained, and a fissure that may have a width of many feet in its upper part, if followed to sufficient depth is likely to end in a series of small cracks whose width is measured in inches rather than feet.* Fissures thus defined may not be necessarily ore-bearing, or they may be too lean to pay in whole or part. A fissure is not necessarily a vein, but a vein assumes the pre-existence of a crack or fissure.

In this dissertation, only such veins are contemplated as have had their mineral contents deposited by filling or replacement along fissures through which the metal-bearing waters and vapors have supposedly circulated.

Bedded deposits, such as the Lake Superior copper and the South African gold-bearing conglomerates are in a class by themselves, one not contemplated in this discussion, although as is well known the workings on them are about the deepest in the world. Both carry native metals in the cementing or binding material of the conglomerates, and the ore bodies are practically continuous and persistent, quite unlike the irregular, often erratic occurrences of ore shoots in precious metal-bearing lodes. It would seem probable that the genesis of two such dissimilar types of ore deposits is as different as their physical characteristics. It is essential to bear in mind that many veins as we now find them, may be mere roots of what they once were, erosion having removed hundreds or even thousands of feet from their original upper portions. According to Lindgren,† in some of the Australian deposits, such as those at Bendigo, although carrying payable ore as deep as 4,600 feet, the gold quartz was probably deposited therein when they were at least 7,000 feet below the original surface. Similarly he believes the gold ores of the Mother Lode, California, to have been formed at depths not less than 6,000 feet from the surface. In the gold deposits of the Southern Appalachians we have perhaps as good examples

*S. F. Emmons' "Cobalt District, Ontario," Mining & Scientific Press, March 18, 1911, p. 394.

†Economic Geology, Vol. 1, p. 41.

of vein roots as are to be found. The amount of material eroded from their croppings since the time of formation Lindgren believes to be greatly in excess of those figures given for Australia and California.* When we consider that although usually lean these gold ores have been found and followed in the Southern Appalachians to depths of over 1,000 feet, their original outcrops must have had a vertical range exceeding 7,000 or 8,000 feet. According to Ransome, the original surface at Cripple Creek, Colorado, was probably from 2,000 to 5,000 feet above the present one.† In the gold districts of Nova Scotia, Faribault‡ has estimated that the erosion of some of the sharpest and highest folds has had the effect of truncating them to a depth, as far as known, of over eight miles. The presumption here is that this vast amount of erosion has removed what was probably the best part of these gold lodes, since the mere stumps that remain have never yet proved of much value. Basing his views on the extreme narrowness of the fissures in the Cobalt mining district, Emmons concludes that the veins there were formed under the pressure of an enormous weight of superincumbent rock at a great depth below the then existing surface; hence before present conditions were reached, the greater part of the original veins had been eroded away, leaving us to-day mere remnants of their original metal treasures. This assumption Emmons supports by a seemingly logical and convincing analysis of the geologic history of the region.§ Whether we accept or not this unpromising and unwelcome view, it appears to be a fact that the change from rich to poor in the Cobalt veins is abrupt, and that this alteration takes place at depths not exceeding 300 feet; in other words, the productive zone is seemingly shallow. Since these observations were made by Emmons, a continuation of payable ore shoots from the Huronian into the Keewatin are reported which if correct rather dispels the pessimistic view held by many that these deposits would not persist below the Huronian, that is below 300 or 400 feet in

*Economic Geology, Vol. 1, p. 42.

†Ibid, Vol. V, p. 462.

‡The Gold Measures of Nova Scotia, and Deep Mining, by E. R. Faribault, Jour. Canadian Min. Inst., Vol. 2 (1899), p. 121.

§Ibid, pp. 394-395.

vertical depth. In eastern North America it is certain that the type of veins found close to the surface, that is, those cutting volcanic rocks, recent flows, the upper surface of which at the time of vein formation can be determined with more or less accuracy, is exceedingly rare. On the other hand, older veins which may intersect the intrusive rocks like diorite and granite; rocks which we know have surely been consolidated at great depths, and which were probably once covered by heavy masses of just such flows as above indicated, are comparatively common.* It is doubtless assuming too much to conclude that a district which has been profoundly eroded like some of those mentioned, is unlikely to contain veins payable and persistent in depth, it is impossible to know how deep the original fissures may have been; it is only possible to collect observations from a comparatively few widely scattered districts all over the world, where deep mining has been attempted. These records are ever open to suspicion, for we may never be sure that a vein supposedly bottomed in lean ore or no ore at all, has not simply temporarily pinched out, to be followed lower down by another shoot as good as any found higher up. Undoubtedly many, possibly most veins in which such conditions have been encountered and finished as far as profitable working is concerned, are hopeless. But the difficulty is to be certain in such cases that a vein or lode is done for all time, and may not perchance again blossom into full bloom of productivity. The probabilities are, however, that in the majority of cases veins or lodes do decrease in richness below 1,000 to 1,500 feet. This cannot always be safely accepted as a rule, save it be one with many exceptions.

It is well known that the North American continent has been relatively stable since the close of the Cretaceous period, and that its land surfaces are older than those of Europe; I refer more particularly to those of the eastern half of North America. Suess has pointed out that the land surfaces of Africa are far older than either North America or Europe. We are reminded in this connection that Africa has as yet produced no great vein or lode deposits of the first rank, the gold "banket" of the Transvaal not belonging to the class under discussion. The lodes of

*Lindgren, Economic Geology, Vol. 1, p. 39.

Rhodesia have been on the whole disappointing, while none of the modern gold mines of Egypt have ever paid a dividend and most of the concessions taken up in 1900 and 1901 have been abandoned.* As before intimated these suggestive observations may be foolish if carried too far in view of our present very incomplete knowledge of Africa, for it is a vast continent, but slightly explored in the geologic sense and may yet yield highly productive ore deposits of the class we are considering. The undoubted great yield of gold from Africa in ancient times was the result of slave labour, a brutal bondage probably unsurpassed in history. It is an interesting reflection in this connection that it was slave labour which made the gold deposits of our Southern Appalachians profitably productive, and that on the whole attempts to operate them have been financial failures in modern times with free labour. The consequent thought from the trend of these observations is that in cases where great areas have been subjected for long geologic periods to erosion by virtue of their stability, the planing down of the surface has been so great that little is left to-day of the original deposits in the old rocks. While such generalizations must evidently be accepted with the greatest caution, there does seem to be some relation between the vertical extent of metal lodes and the geologic age of the area in which they are located. In other words, the more stable an area has been through its geologic history the greater the erosion to which it has been subjected, and the less productive have been its mineral lodes.

Instances of the discovery of new deep-seated ore shoots are not uncommon in well established metal-producing districts where systematic exploration and development are being carried on. A number of such cases might be cited, including the famous Comstock and some of the old mines on the Mother Lode in California. At Guanajuato, Mexico, the lower reaches of the Valenciana lode on the "Veta Madre" are to be tapped at a vertical depth of 2,000 feet below the collar of the Nueva Luz shaft, and about 3,300 feet on incline of vein from the top of the old Valenciana shaft, by new workings with a reasonable assurance of finding large bodies of payable ore. The Mexican gov-

*Maclaren, "Gold," p. 414.

ernment, doubtless after obtaining professional advice, has had sufficient confidence in the success of this undertaking to grant a subsidy to the American company doing the work for each metre of depth attained in this new (Nueva Luz) shaft; the expectation being that the ore bodies thus opened for exploitation and the incidental unwatering of the old Valenciana workings will bring new life to this once enormously productive camp. Such is, I believe, the only instance in which the Mexican government has directly given such pecuniary aid to a mining enterprise, showing thereby confidence in the persistence with depth of this great mother lode "Veta Madre."

In Australia, the Victoria Reef Quartz Mine at Bendigo has attained a vertical depth of over 4,600 feet, but as the ore body at this level is too lean to pay it has been decided to sink to a depth of 5,254 feet, the government bearing half the cost. Between the 4,254 and 4,154 feet levels considerable coarse gold was found, some pieces weighing a half ounce often passing through the stamps. The average of the ore was about $17 per ton. The gold itself has not decreased in purity nor was it in unusually fine particles as had been expected. This at present is the deepest gold mine in the world, and is situated centrally on the famous New Chum lode from which many millions of dollars have been obtained.*

H. Kilburn Scott, in the June, 1911, issue of the *Mining Magazine,* calls attention to the Morro Velho mine in Brazil, belonging to the St. Juan del Rey Gold Mining Co., as the deepest gold mine in the world. He states he recently had occasion to visit this mine, and found it almost 5,000 feet in vertical depth; the ore has an approximate dip of 45°, so that the depth along the slope is about 7,000 feet.

It is evident there exists among experienced mining people a belief that in profoundly mineralized regions, it is reasonable to expect the deep sections of great vein systems will continue to yield abundantly of their treasures whenever the costs of exploration and extraction are not prohibitive. According to H. C. Hoover at Kalgoorlie, West Australia, there are several

*Wilfred J. Rickard, The Mining Magazine, Oct., 1910, p. 281.

properties upon which ore bodies have been discovered in depth where none or but small ones existed at the surface. In other instances in this district a marked increase of value has been noted with depth.* This paper of Hoover's was written eight years ago. Whether this last characteristic has been maintained I do not know; the latest reliable information obtainable is to the effect that several of the deeper mines in the Kalgoorlie district are producing abundantly at the 2,600 to 2,800 foot levels. Hoover considers that the profound structural features of the district are such that this width and continuity of the fissures are well assured, but that the ore will occur continuously with the lodes "is a matter which admits of less finality."

Lindgren likewise says these deposits have no definite boundaries, either horizontally or vertically, other than those determined by the decrease of assay value of the rock in any one direction.† It would be a mistake to draw any general conclusion from conditions at Kalgoorlie. They are not unique, though perhaps unusual. There seems to be little reason to assume that depth below the surface has *per se* any direct relation to the extent and richness of the lodes. Recent experience at Tonopah, Nevada, tends to show a decrease in value with depth with a compensating tendency to wide lateral extent of pay ore in the veins, limited only by the characteristic block faulting of the district. However, it is not to be inferred from this that a vein or lode or series of veins are necessarily continuous laterally through the full extent of such a block. Evidently such is not the case, for the veins appear to cease laterally as they do in depth even before being cut by a fault or intrusive dyke. But the practical point in this instance is that the chances of finding ore are overwhelmingly greater in lateral exploration than in vertical. An interesting classical case may be cited in this connection. At Joachimstahl, Bohemia, the veins have been divided into two classes, first, those rich in the upper levels but which grow poorer with depth, and second, those fissures possessing fairly constant and persistent values as deep as 2,000 feet. A

*Trans. Institution of Mining and Metallurgy, Vol. XIII, p. 12.
†Ibid, Vol. I, p. 533.

peculiarity of the latter class is that some of the fissures reach the surface, not as mineralized veins, but as narrow, barren cracks.* A number of years ago W. P. Blake observed that when a lode cuts different formations we must expect its contents to change with the varying character of the rocks, either downward or horizontally. The change in Cornwall, England, from copper ore to tin ore in passing from "killas" into granite is a good and classic example of this. When lodes traverse stratified rocks parallel with bedding the conditions as respect the chemical constitution of the walls may be assumed to be alike for great distances, and therefore we may look for similar mineral contents as far as these conditions extend. But when the lode traverses a group of beds transversed to bedding, uniformity of mineralization either in quantity or quality need not be expected.†

While it is not the purpose of this paper to discuss theories of mineralization and ore accumulation, it might be observed in passing that the lateral secretion hypothesis championed many years ago by Sandberger, as well as more modern views regarding the potency of capillary circulation at great depth, particularly in basic rocks, do not seem to have been sufficiently appreciated as an agent of ore deposition. Blake defines this circulation as an endosmotic flow through visible pores of rock inward to fissures.‡ Sandberger's view was "that the material for filling of veins is derived from the country rock through gradual leaching by seepage water, which brings the dissolved substance from both sides to the vein fissure, where it is then converted by chemical decompositions into insoluble gangue minerals and ores and so deposited.§

This theory was vigorously assailed by Posepny, but it is difficult in view of one's own observation and practical experience not to sympathize with some of Sandberger's ideas. In fact it would seem probable that the deep underground circulation,

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*Beck, Nature of Ore Deposits (Weed's translation), p. 285.

†Persistence of Ores in Lodes in Depth, W. P. Blake, Engineering & Mining Jourl., Vol. LV (1893), p. 3.

‡Ibid, p. 3.

§F. Sandberger, Untersuchungen über Erzgänge, 2tes. Heft, Wiesbaden, 1885, p. 159. Trans. Am. Inst. Mng. Eng., Vol. XXIII, p. 249.

which concentrates metallic minerals at convenient voids in quantities sufficiently large to pay for extraction, is both upward and lateral, and that both seepage and capillary circulation contribute no small increment. That the metals we now find in deep-seated ore deposits were derived wholly from indefinite depths is a theory difficult of complete acceptance, in view of the persistent and extensive mineralization usually encountered as incidental constituents of magmatic rocks, usually closely associated with precious metal deposits. Van Hise says on this head, and his view appears to be not unlike Sandberger's, "I have little doubt that the metallic constituents of ores are in large part derived from the igneous rocks which have been intruded or extruded into the lithosphere; and especially is this true of the basic rocks."*

Anyone who has studied the precious metal deposits of our southwestern states and territories, of Mexico and especially in the great Andean region of Central and South America, must have been impressed by the highly mineralized character of the accompanying igneous rocks. To assume as probable a leaching of the metallic minerals contained in such rocks by aqueous solutions circulating laterally through them, by capillary attraction in the massive, and by seepage and flow in the fractures, followed by a subsequent deposition of the metallic burden in the adjacent voids or by replacement of rock and associated minerals, seems but a natural and logical conclusion. It is true that with the exception of iron the amount of metal found by analysis in such rocks is usually exceedingly small, but we must realize that the volume of these rocks is very great compared with the size of the ore deposits, and that time reckoned by the geologic calendar is very long. I have alluded elsewhere to the general existence of traces of gold in the volcanic rocks of the Great Basin in Nevada, Arizona, California and Mexico.† Since then I have had opportunities of noting the frequent presence of pyrite containing traces of gold in the andesites of the Andes Mountains in Colombia, South America. Neither here nor usually elsewhere, can anyone trace with certainty the origin of the metals consti-

*Trans. Am. Inst. Mng. Engrs., Vol. XXX, p. 91.
†Mng. & Sci. Press, Sept. 7, p. 309.

tuting these ore deposits to the metallic minerals in the surrounding rock, but it is difficult under the circumstances not to believe these solidified magmas have contributed largely to this result. Posepny rather scouts the idea that any considerable amount of metal could be thus derived, on the contrary he maintained that the pyrite and chalco-pyrite frequently found as an incidental ingredient of the igneous rocks closely associated with ore deposits, to be the consequence rather than a contributory cause of the ore deposit.*

The old German miners recognized the value of pyrite as an indication of the proximity of ore; they gave the name "fahlbands" to zones or belts of pyritized country rock, and observed that fissures intersecting such zones are usually locally enriched. For example, in the Kongens Mine at Kongsberg, Norway, the ore shoots are usually, but not invariably, confined to the "fahlbands." A short distance from these zones the veins are apt to be barren. This famous old silver mine is now probably about 3,000 feet or more in vertical depth, and has been a great producer since the year 1623. Most of the silver is in the native condition. It has been assumed, and I think logically, that the metalliferous portions of this interesting lode are the consequence of the associated "fahlbands." Intimate associations of pyrite and native silver have also been observed in several Mexican mines, and the inference has been drawn in such cases that the pyrite was in some way connected with the presence of native silver.† At Batopilas, according to Collins, the native silver occurs with calcite but below the pyritic zone.‡ On the Mother Lode in California it has been observed that pyrite does not appear to have been the direct precipitating agent for gold, but to have facilitated its precipitation by acting as a depository or base for the precipitate. Instances have been noted where the gold appears to have been precipitated upon the pyrite in preference to associated quartz. The same influence that precipitates the gold seems to have also precipitated the pyrite. The

*Trans. Am. Inst. Min. Eng., Vol. XXIII, p. 254.

†Trans. Institution of Mining & Metallurgy, Vol. III, p. 425.

‡Ibid, p. 441.

quantity of pyrite in solution being in excess of the gold is naturally precipitated out first.*

A remarkable instance of the apparent influence of pyrite upon gold deposition has been noted by Scott at the Morro Velho mine in Minas Geraes, Brazil. He states that this great lode consists of lenticular shoots of quartz enclosed in schists. They follow the cleavage or bedding of the enclosing rock; the quartz is often associated with arsenical pyrite, pyrrhotite and carbonates of lime, magnesium and iron. When these sulphides are lacking, gold in appreciable quantity is entirely absent. The most productive matrix is a compact mixture of quartz and pyrite enclosing varying quantities of country rock. The Morro Velho lode shows little appreciable difference in size or gold value throughout its great depth. The enclosing rock, though generally speckled with pyrite at the contact, contains only a small amount of gold. The pure quartz in the lode is seldom auriferous, and the pure pyrite (unless it be arsenical) is hardly ever rich.†

According to Derby the Morro Velho lode was characterized by the presence of free carbon either disseminated throughout the ore or segregated in zones of movement.‡

Among the minor causes of enrichment of ore deposits near the surface is the mingling of solutions from cross fissures. Van Hise attributes the principal cause of ore shoots to them and it is indisputable that at such intersections ore bodies are common. But it does not appear that bonanzas or local enrichments in deep lodes are necessarily dependent upon such influences; in fact, deep-seated ore shoots are generally characterized by comparative dryness. As a rule the greater the depth reached the less water there is; in other words, it would seem in most instances that after a certain level has been passed the amount of water encountered varies in inverse ratio with the depth, the deepest workings being the dryest.

In connection with the topic of this paper, attention may be directed profitably to a subject recently discussed by Horace V.

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*Pritchard, Trans. A. I. M. E., Vol. XXXIV, p. 459.
†H. Kilburn Scott, Trans. A. I. M. E., Vol. XXXIII, pp. 413 and 429.
‡Trans. A. I. M. E., Vol. XXXIII, p. 287.

Winchell regarding the differences in surface appearance and mineralization between southern ore deposits and those formerly covered by the continental ice sheet, or roughly speaking north of the 45th or even 40th parallel of latitude in Eastern America.* This geologist points out what probably most of us know, did we stop to consider, that even were the rocks of these regions unplaned and undegraded by the ice sheet, the natural oxidation and decomposition of their vein croppings would be much slower than in southern, especially tropical, latitudes, hence the consequent secondary enrichment of such lodes is necessarily less. The planing down by the great continental ice sheet of the Pleistocene or Glacial period, must have removed much if not most of the oxidized portions of these outcrops, except in places which may have been sheltered from this titanic leveller by reason of local topography or perhaps minimized by some other cause. Hence what remains to-day is either the roots of deposits of secondary ore or else primary ore veins which are likely to extend downward to considerable depths. Winchell claims that boreal regions seldom contain extensive deposits of secondary ore, that is upper portions of primary deposits enriched by secondary deposition. That such roots are likely to be as productive as secondarily enriched lodes in unglaciated regions is not to be expected. Speaking in very general terms their primary character would tend to render them low grade, but with the compensating advantage of probable persistence with depth. I take it that the practical point which Winchell here desires to emphasize is that in glaciated regions and those far north or south where, by reason of the cold, but little alteration could take place, the lode outcroppings are quite different from what may be expected in more temperate, especially tropical countries. In warm regions outcrops may even be deceptive, since by excessive oxidation and decomposition a larger and richer deposit might be indicated than subsequent development exposes. In glaciated areas, the planed down rocks are likely to expose the lode at the surface in much the same condition as it exists a hundred or more feet in depth, that is, all superficial alterations have been sliced off, leaving the unaffected stump cropping

*Mining Magazine, Dec., 1910, p. 436.

to the light of day. Even though such veins be but the roots or stubs of once greater lodes, and are thereby likely to be of infinitely less value than when in their pristine condition, there is a compensating advantage in that the true character of the veins in such glaciated areas may be determined with comparative ease by simple surface trenching. In more southern unglaciated areas considerable depth must usually be attained before the original character of a lode can be studied with accuracy.

The most serious difficulties to overcome in deep mining are threefold—hoisting, high temperatures and rock pressure. The mechanical problem of hoisting from depths of 5,000 feet is probably the least of these, and has been pretty well worked out in South Africa and at the copper mines on Lake Superior. When such shafts depart from the vertical in part of their course the best practice seems to be to hoist in stages; in fact it is not unlikely such a system may be found in many cases the most economical even where the shafts are wholly vertical, especially now that electrical appliances have reached such a high degree of efficiency.

The normal increase of rock temperature with depth is a more serious matter, although so far it has been capable of control, for while there is a steady rise of something like 1° F. for each 208 feet (beginning with an average of 60° F. at surface) of depth in the South African gold mines* and 1° F. for each 103 feet in the Lake Superior copper mines,† good ventilation overcomes much of the discomfort from this source. In cases where the surrounding rocks are chiefly or wholly of eruptive origin, the rock temperatures are likely to be even higher. In the Comstock, for example, at the 2,000 and 2,100 feet levels it ranges between 111° and 119½° F.‡ In the Savage Mine on the same lode, at a depth of 2,200 feet a spring of water having a temperature of 150° F. has been tapped.§ According to

*Trans. Institution Mining & Metallurgy, Vol. XV, p. 415.

†Chamberlain & Salisbury, Geology, Vol. I, p. 543.

‡Lord Comstock, Mining & Mines (Monograph, U. S. Geol. Survey, 1883), p. 387.

§Trans. A. I. M. E., Vol. VII, p. 71.

Becker* the water that flooded the lower levels of the Gold Hill (on Comstock Lode) mine during the winter of 1880-81, had a temperature of 170° F. In the Victoria Reef Quartz shaft at Bendigo the rock temperature is about 110° F. the water issuing therefrom 114° F.† At the bottom of the Nueva Luz shaft, 2,000 feet deep, at Guanajuato, Mexico, rock temperatures of 106° F. are now being encountered.

It must not be assumed that the deeper one goes into the crust of the earth the greater the heat, for some increase in rock temperature may be due to local phenomena such as oxidation of the sulphides or the kaolinization of the feldspars. Thus, in the Comstock, the rise of temperature is not progressive below the 2,000 foot level. In fact there seem to be belts or zones of high temperature which rises to a maximum at about 2,200 feet, then followed, as we proceed in depth, by a slight decrease. It should not, however, be concluded from this that there is not in general a normal rise of rock temperature as we penetrate into the earth, for there undoubtedly is such in all kinds of rocks; in other words, the earth becomes progressively hotter towards its centre. There have been many calculations as to what this increment of increase may be; but it is safe to say, as a rule, they are far from accurate, for as we have seen, local conditions often import disturbing influences.

The increase of rock pressure in deep workings is probably the most serious difficulty of all—one likely to make the methods of supporting the roof increasingly costly with depth. It seems likely that steel and concrete and especially waste rock filling may be used in such instances to marked advantage, where in higher levels timber would suffice. One thing is certain, that in most cases whatever methods are adopted the expense is likely to increase out of all proportion to the profits. Moreover the outlook for a decrease of cost in this respect is not hopeful, unless it be in the direction of flushing with tailing sand and fine dump material. These methods or at least schemes of a somewhat similar character have been carefully studied and used in the anthracite coal district of Pennsylvania and in the gold mines of the Transvaal.

*Geology of Comstock Lode, p. 38.
†The Mining Magazine, Oct. 1910, p. 282.

In summing up the discussion attempted in this paper, the writer is impressed by the inconclusiveness of his conclusions. In fact the nature of the subject precludes definiteness, except in a few very broad principles. Probably it may be generally conceded that fissure veins will not carry payable ore to indefinite depths. It must be recognized that a deep ore body which may not pay to work to-day, might be profitable in the next decade by reason of improved mechanical and electrical equipment as well as greater economy and efficiency in milling practice. General experience throughout the world tends to the conclusion that metal-bearing veins of all kinds, with some exceptions, show a marked decrease of value as depth is attained below the 1,500 or 2,000 feet levels. Among the exceptions might be cited the Perseverance Mine at Kalgoorlie, Australia, where the bottom levels are richer than the intermediate horizons between 1,300 and 1,750 feet.* Again, at Mysore, India, at several points in the bottom levels the gold content is high; thus for instance at the 2,790 foot level in Tennant's section, an average was obtained of about $37 per ton, for over four feet, and at the 4,010 level in Bullen's section (Ooregum) the vein is 15 inches and averages 1½ ounces gold per ton.† Maclaren says of this great Mysore ore shoot that it has an average width of about 4 feet, and has maintained this general width and value for a depth on its pitch nearly 4,000 feet, and it is certainly the most notable shoot known in the history of gold mining.‡ At the Weihi Mine, New Zealand, the veins are characterized by the continuity of pay ore both in horizontal and vertical extension.§ It is certainly a notable fact that as far as the writer is aware few of the deep metal producing lodes other than iron are located in districts which have been subjected to glaciation. The copper deposits of the Lake Superior region are an exception. It is going too far, however, to assume that because of this the lodes have been eroded away and we may never expect deep mining to be possible in such areas. Our knowledge is too slight to accept any such general conclusion. The fear that this condition may be a fact

*Mining Magazine, Feb., 1911, p. 80.
†Ibid., p. 81.
‡Gold, p. 255.
§Bell, Economic Geology, Vol. I, p. 747.

is perhaps justifiable from our experience throughout the world, and in some degree is supported by deductive conclusions based on geologic observations. This question is a peculiarly timely one. It is, moreover, a very vital subject to Canada in view of the rapid development on the rich ores of Cobalt and Porcupine.

DISCUSSION.

MR. J. PARKE CHANNING: A few years ago the general impression prevailed that values were confined to the upper levels. This summer I re-visited the Gogebic Iron range which I had not seen for twenty years. At that time the Montreal mine was down about 500 feet, and those in charge did not think the ore would continue to a greater depth than a thousand feet. On the occasion of my visit to the Montreal mine last summer, I found that the workings had reached a depth of 2,500 feet, and that there was practically no change in the character or quality of the ore.

DR. J. F. KEMP: There are old veins in Bohemia which have been followed down to a depth of about 3,600 feet, where, I think, the ore was of excellent grade.

MR. T. A. RICKARD: This is a subject in which I have always taken a keen interest. I agree with the previous speakers that the general trend of opinion has undergone considerable change in the last twenty years. I remember in 1891, Prof. Wm. P. Blake read a paper on the subject, arguing in favour of the indefinite persistence of profitable ore in depth, which opinion at that time I attempted to controvert. Those who argued on the side which I then assumed were decidedly in a minority, and I remember discussing the question with John B. Farish, an engineer, having the widest acquaintance with Western mineral deposits. His opinion was that while a discussion on the subject would be profitable, he thought it would be extremely desirable to burn the records of the discussion immediately thereafter. He had an idea that the ventilation of the truth would hurt mining. I may presume none of us here hold that view, but we believe the elucidation of fact is the best way to help industry. The whole

discussion of the subject has been changed by the understanding of the occurrence of secondary enrichment and the phenomena incidental thereto. We speak of the occurrence of ore below the water level. I think in this subject as in some others we are quite apt to confuse the continuity of quartz with the persistence of ore. This is an economic and not a geologic problem. Mr. Garrison, speaks of 'roots' of veins. I do not like the expression 'roots.' Mr. Faribault has also made use of it in describing the gold veins of Nova Scotia. It is a fact that the erosion in Nova Scotia may be estimated to have extended to a depth of five, six, seven or eight miles; but I find myself quite unable to believe that a vein of quartz four inches wide found at the surface to-day, persisted from the imaginary horizontal surface eight miles above, especially when I find by sinking a winze that four inches of quartz 'peters out.' This matter has recently been debated before the Institution of Mining and Metallurgy in London. A gentleman on the Rand, named Schmidt, suggested the measurement of ore in depth in that district. This, of course, had a sinister connection with the large financial operations conducted in London. Mr. Marriott, an engineer of the highest standing, connected with one of the biggest houses, arose and undertook categorically to assure the Institution of Mining and Metallurgy that he had evidence showing that the veins do not become poorer in depth, leaving out the upper zone of oxidation. Unfortunately, I was not present at that meeting, because if I had been I should have asked Mr. Marriott to give the evidence for so serious a statement. Subsequently in print, in a little magazine of which I am the editor, I asked the question and I requested Mr. Marriott to substantiate his statement, because it seemed to me that if true it would be of great help to the science of geology, to the industry of mining, and to the mining market in London, and I thought those were quite sufficient reasons to induce Mr. Marriott to prove his case. Mr. Marriott for very good reasons, which I appreciate—there is, of course, a little humor in the situation, which I also appreciate—did not comply with my request. He could not say very much. But I do not believe for a moment that he can prove his case. Subsequently, one day we were in our new Mining and Metallurgical

Club and Mr. Marriott came up to me and said: "I will give you some information and facts which will, perhaps, enable you to be more accurate." To which I replied "If possible." I went to his office and he was good enough to offer me a good deal of information in support of his contention, but it was most unconvincing. I may be indiscreet in stating just what occurred, but I am willing to assume the risk, as I deem it useful to do so. Among other evidence he submitted was a longitudinal section of the East Rand Proprietory mine. This exposed workings for a distance of 12,000 feet on the lode or reef as they call it there. After studying this stope map carefully I was enabled to come to a definite conclusion. The ground worked out was coloured blue-grey, the profitable ore was shown yellow, the unprofitable material red, and the doubtful ore was marked orange. The levels were indicated. After looking at the stope section I concluded that I would prefer the ore from the first 500 feet to the next 1,000 feet in depth, that the first 1,000 feet was worth more than the rest of the mine to the centre of the earth; omitting the oxidized and enriched zone, I would rather have the next 500 feet than any deeper 1,000 feet. Evidence confirmatory of this view has been given by so trustworthy a witness as Mr. Hellmann, and I confess without cynicism or malice, that I view with suspicion the seniments, in this connection, of those involved in the financial operation incidental to the industry of mining operations.

ON THE OCCURRENCE OF MANGANESE AT NEW ROSS IN NOVA SCOTIA.*

By H. E. Kramm, Ithaca, N.Y.

(*Annual Meeting, Toronto,* 1912.)

Manganese ores occur in many widely scattered localities in Canada; but so far have been obtained in commercial quantity from occurrences in the Maritime Provinces of Nova Scotia and New Brunswick only. Manganese mining was undertaken in Nova Scotia as early as 1861. Operations, however, were conducted on a very small scale, for the total production between the years 1861 and 1872 is estimated to have not exceeded 1,500 long tons. No reliable data in respect of this period are apparently available. The maximum production, 691 tons, was attained in 1887; of this 578 tons, valued at $14.220, were exported. The highest average value per ton was obtained in 1881. In that year 200 tons of ore were exported, valued at $18,022, or $90.11 per ton. Later years show a declining and somewhat erratic production.

The manganese ore of Nova Scotia is usually found in the form of oxides in association with sedimentary rocks, limestones, shales and conglomerates of the Lower Carboniferous series.† In the limestone which carries more or less magnesia, and which quite often is brecciated the ore occurs in flat nodules, seams and pockets. Its mode of occurrence in the shale is similar; but it is more commonly found in connection with the former rock, and less frequently in the conglomerate. Gilpin (loc.cit.), also mentions deposits of manganese in fissure veins in granite.

As to the origin of the manganese, Penrose believes‡ that it has been derived from the decay of Paleozoic rocks and the

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*Published by permission of the Director of the Geological Survey of Canada.

†See Gilpin, Notes on the Manganese Ores of Nova Scotia, Trans. Roy. Soc. Can., May 22, 1884, pp. 8-9.

‡Ann. Rept., Arkansas Geol. Surv., 1890, vol. 1, p. 539.

breaking down of manganese carrying minerals in them. The manganese was converted by organic acids into soluble salts, which were carried along by waters, were finally precipitated as oxides or carbonates, and, the latter being unstable, were converted into oxides. A subsequent breaking down of the rock in which the manganese was deposited would account for the occurrence of nodules in clays and residual soils.

Manganese at New Ross.

New Ross is a small settlement to the southwest of Windsor, Nova Scotia, with which it is connected by a waggon road, 28 miles in length. The manganese deposit now being developed occurs about 10 miles to the north of New Ross. On account of the poor condition of the road, oxen are used for hauling of supplies and ore. A waggon-road connecting directly with Falmouth and tide water is in course of construction and will shorten the distance to the mine considerably.

There are two deposits of managanese, both being fissure veins in granite, and known as the "Old Mine" and the "New Mine" respectively. Both veins have approximately the same general direction, about N. 50 E., with a steep dip of between 70° and 90°, and a width varying from zero to 70 inches as a maximum.

Manganese was first mined at the Old Mine in 1900, but the work after progressing for a period of about three years was stopped, because of litigation. The workings had at that time reached a depth of 115 feet and were still following the orebody. Prospecting of the New Mine, which is being developed at the present time by the Nova Scotia Manganese Company, was begun in 1902 but development work was not started until 1910. At the present a single compartment shaft, with manway, has been sunk to a depth of 160 feet and a level has been driven at a depth of 150 feet following the orebody.

The granite in which the deposits are found is a batholith which covers many square miles to the south of Windsor. Its trend is approximately east and west and gives rise to a series of low ridges which run north and south. The granite is composed of orthoclase, quartz, and biotite, and has a rather porphyritic

appearance, which is caused by the crystals of orthoclase attaining a length of one-half to one inch. These are of a milk-white colour, having a slight pinkish tint, thus giving to the rock a mottled appearance. The biotite occurs in hexagonal crystals which are from ⅛ to ¼ of an inch in diameter and are violet tinted. The biotite is easily decomposed and broken up by weathering and gives rise to blackish-brown stains, which colour the surrounding rock-mass. Quartz is less prominent and is colourless.

The granite seems to have been scoured by glacial erosion. At places smooth, level areas are exposed, upon which rest more or less rounded boulders of granite and occasionally smaller fragments of metamorphosed sedimentary rocks. The limited amount of overburden facilitates prospecting. The presence of manganese is indicated by float which can be traced to its source. Another indication is the presence of red ochre, found on the surface in fissures in the granite and known to the prospector as "paint." Wherever paint is found manganese is likely to be discovered at depth.

The old, as well as the new mine, present features of ore deposition of great similarity and permit the dividing of the ore-body into four zones, which are as follows, from the surface downward:

The first zone consisting of a gossan, is made up of hematite, limonite and goethite, the latter being a very prominent mineral. While the part near the surface consists of a solid mass of iron oxides, a few feet from the surface they become floury and change into red ochre. The thickness of the iron cover varies from 10 to perhaps 15 feet.

The second zone consists principally of pyrolusite with small quantities of manganite. From the first zone there is a gradual transition into the second zone. Within the ochre are found masses of pyrolusite, their quantity increasing with depth and at places filling the entire width of the fissure vein and making sharp lines of contact with the granite wall. At other places again, within the same zone, the entire fissure may be filled with ochre. The ore is very pure and highly oxidized, consisting in

the upper portion entirely of pyrolusite, while in the lower portion manganite represents a considerable percentage.

Crystals of pyrolusite pseudomorphous after manganite are particularly common, in fact, most of the highly oxidized zone consists of a felted mass of these crystals or else stout prisms protruding from a solid groundmass of pyrolusite. At first sight these crystals appear to be manganite. They have its bright metallic lustre, but they are easily scratched by the finger nail and readily soil the hand.

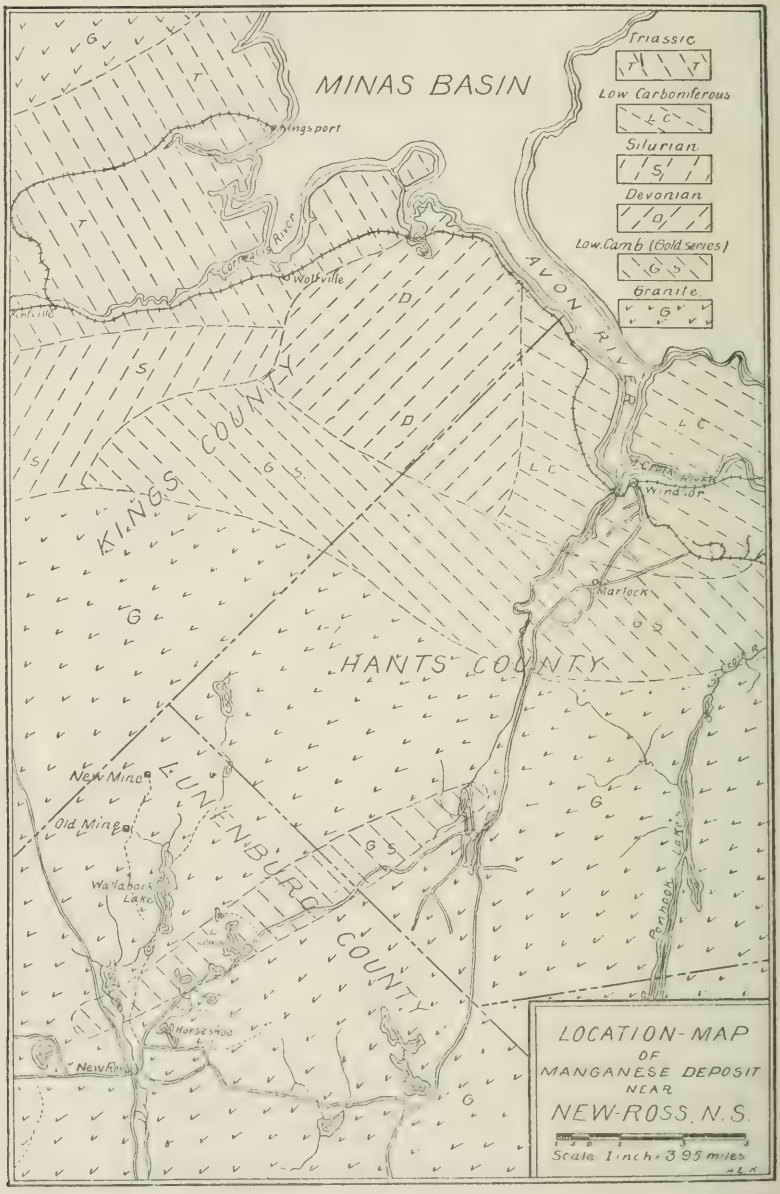
From the same zone the writer has also obtained a specimen of pyrolusite pseudomorphous after a carbonate, probably rhodochrosite. The rhombohedrons are well preserved and have a diameter of about 1 cm.

In the third zone the pyrolusite is less abundant. The ore becomes more massive, harder and assumes a steel blue colour. It is made up of manganite and psilomelane, and only occasionally are there found clusters of pyrolusite crystals in the cavities of the hand specimen. Ochre is present as a gouge or may fill the entire space between fissure walls, but is less prominent compared with its presence in the second zone.

The fourth zone consists of a hard bluish-brown ore, principally composed of a mixture of psilomelane, oxide of iron and some manganite. None of the specimens investigated by the writer showed pyrolusite.

Of course there is no definite dividing line between the different zones, but they grade into each other. With depth as has been said, ochre, filling the entire fissure becomes less frequent and at about 75 feet from the surface these pockets disappear entirely. At all depths, however, a certain proportion is usually present as a gouge.

That the degree of oxidation of the manganese is highest near the surface and decreases with depth is clearly shown by the following table of analyses (giving the average content of manganese, manganese-dioxide and iron) of test lots taken from varying depths below the surface:


MINAS BASIN
Kingsport
Cornwallis River
Wolfville
AVON RIVER
KINGS COUNTY
HANTS COUNTY
FUNDY BAY
Windsor
Maitland
New Mine
Old Mine
Wallabach Lake
Horseshoe
New River
Triassic
Low Carboniferous
Silurian
Devonian
Low. Camb. (Gold series)
Granite
LOCATION-MAP
OF
MANGANESE DEPOSIT
NEAR
NEW-ROSS, N.S.
Scale 1 inch = 3.95 miles

Quantity Represented	Mn	MnO_2	Fe	MnO_2 calculated to satisfy Mn	Where Found
Barrels*	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Feet
7	61.37	91.04	0.50	9.0	28-42
28	50.56	89.76	0.81	95.8	28-42
90	60.54	70.50	0.77	95.8	42-75
146	59.12	55.60	1.94	93.5	42-75
100	59.40	53.75	3.22	93.9	75-90

Analyst, Jos. W. Phelan, Boston.
*Each barrel contained approximately 500 lbs. of ore.

It may be seen that while the manganese content varied very slightly, the maximum difference being 4.71%, the manganese dioxide which was separately determined in each sample and which means the percentage of pyrolusite, declined within a very short distance from the surface 37.20 per cent. The content of iron on the other hand gradually increased.

The limited exposures of the new mine, while showing in a general way a great similarity in the nature of the ore deposit, show that oxidation to a greater depth has taken place. Thus hand specimen obtained from the 150-foot level consist principally of pyrolusite with some manganite, and at that depth the ore alternates with pockets of ochre. As in the old mine pseudomorphs after manganite are common.

Origin of the Ore.

Penrose (loc. cit.) has suggested that the breaking down of minerals carrying manganese contained in the crystalline Paleozoic rocks and in igneous rocks liberates the manganese; hence these rocks are probably the source from which all manganese deposits have been derived. The occurrence of vein deposits in granite suggests the granite itself as the source of the

manganese. Of the minerals of which it is composed, biotite and orthoclase are most likely to carry it. Tests made by the writer on fresh granite showed orthoclase to be barren of manganese, but the biotite gave strong reactions for this element. That biotite is the least stable of the minerals constituting the granite can be readily observed in the hand specimen. It loses its lustre and crumbles. Blackish-brown stains colour the surrounding orthoclase and quartz. From this it appears that manganese and iron, both being about equally soluble in water, are taken into solution by meteoric waters. These waters when freely exposed to the action of air, which would be the case in fissures, are forced to precipitate their mineral content, which is deposited in the form of oxides or carbonates of manganese and iron.

The uniform character of the fourth zone, that is the depth at which probably no secondary alteration has taken place, suggests that the particular oxide of manganese which was deposited, is psilomelane and that limonite was deposited with it, the two oxides forming a homogeneous mixture. From observations made by the writer at localities in New Brunswick, where manganese is found deposited on pebbles and boulders in creek beds, there seems to be a preference for the deposition of psilomelane. The film deposited usually has its characteristic colour and lustre. That carbonates were also deposited at New Ross is shown by the presence of pseudomorphs, but the quantities deposited remain a matter of conjecture. There is even the possibility that the entire deposit was laid down as carbonates, siderite and rhodochrosite, and that these, being unstable, liberated CO_2, leaving a mixture of iron and manganese oxides. This, however, is not probable, since the breaking down of the ores would leave it in a more porous condition than it is found in the lowest zone, and, furthermore, the escape of great quantities of CO_2 would surely have left more traces in the upper zones.

Changes of a secondary nature produced conditions as they are found at present. The oxide of manganese being under certain conditions more soluble than the iron oxide went into solution. The iron capping which is barren of manganese is a proof of the greater solubility of the manganese. Psilomelane, there-

Surface plant at New Mine, New Ross, N.S.

GOETHITE FROM GOSSAN.
Reduced one-third diam.

PYROLUSITE PSEUDOMORPHOUS.
After Rhodochrosite. Actual size.

fore, probably went into solution and was redeposited as the hydrated and higher oxide of manganese—"manganite." This seems to explain the pockets of limonite, which alternate with bodies of manganese ore from the surface to the fourth zone, a migration of the ore to a certain extent having taken place. A further oxidation and dehydration again produced pyrolusite and accounts for the many pseudomorphs after manganite. Evidence which points to the derivation of the pyrolusite from psilomelane is the fact that even in the purest pyrolusite, chemical analysis shows appreciable quantities of BaO which psilomelane contains, and which it seems remained with the manganese ore through all its secondary changes.

In closing the writer wishes to express his obligation to Dr. H. W. Cain, of Falmouth, N.S., for information and courtesies.

ON THE ORIGIN OF THE PORCUPINE GOLD DEPOSITS.

By Reginald E. Hore, Michigan College of Mines, Houghton, Mich.

(*Annual Meeting, Toronto,* 1912.)

Gold occurs at Porcupine in quartz bodies of very numerous forms. Many of the deposits may be classed as one of four types*:—1, quartz veins; 2, quartz vein systems; 3, quartz masses; 4, quartz-ferrodolomite lodes. The quartz veins are well defined, single fissure fillings, commonly varying considerably in thickness and forming numerous lenticular portions, but having on the whole a somewhat tabular form. The vein systems are made up of two or more veins, close together and more or less parallel. The quartz-ferrodolomite lodes are made up of ferrodolomite traversed by numerous veins and veinlets of quartz. The quartz masses are of irregular and for the most part of unknown shape. Some have been described† as kidneys and chimneys. Others show a tendency to elongation in two directions and appear to be members of a series of thick lenticular masses lying at intervals along a fissured zone.

The rocks enclosing ore are of several different types. A common one is a gray sericite-carbonate‡-quartz schist that was probably originally a quartz porphyry. Other wall rocks include basalt, porphyrite, conglomerate and gray slate.

It appears that neither the form of the opening or the character of the country rock were the chief factors in the formation of the ore bodies. These are important factors to be considered

*Illustrations of these types were given in Canadian Mining Journal, November 1, 1910, pp. 649-656. Descriptions of a number of the deposits are given by A. G. Burrows, in his report on "The Porcupine Gold Area," pp. 20-31, 20th Annual Report, 1911, Bureau of Mines.

†P. A. Robbins, Annual Report Hollinger Mine, Jan. 1, 1912, p. 6.

‡Sericite and ferrodolomite are characteristic also of many gold-quartz veins of California and Victoria. See Lindgren, Eng. and Min. Jour., Mar. 9, 1905, p. 459. The same minerals are characteristic also of rock alterations in the Kalgoorlie goldfield.

in the study of the individual ore shoots; but will not enter into the present discussion. Attention is here directed rather to characters common to all. These characters indicate a common origin and by their nature give some clue to the process involved in the formation of the deposits.

Characters of the Gold Ore Determined Optically.—The ore in all cases is native gold* in pyritic quartz. The gold is partly in coarse grains, visible to the naked eye, but is chiefly in very minute particles, intimately associated with pyrite. Some of the gold is actually intergrown with pyrite; but most of it is not. Some of the gold intergrown with pyrite is in very small grains, visible only with the aid of a microscope, and it is quite probable that there are similar particles which are not visible on account of their smaller size. Some gold is in calcite or ferrodolomite. (See microphotos 4a and 5a.) Galena, sphalerite and chalcopyrite† occur frequently, but in small quantity. Tourmaline, feldspar‡, scheelite and some yet unidentified minerals also occur.

The pyrite associated with native gold is in some cases in large, well-formed crystals (see microphotos 6a and 7 a); but most of it is in small and, for pyrite, very poorly-formed crystals.

The gold and pyrite are not distributed uniformly through the quartz and are commonly most abundant near the wall rock (see microphotos 9a and 10a) or pieces of rock enclosed in the quartz. Large areas of vein material are quite free of opaque minerals.

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*It is not unlikely that some tellurides of gold occur; but, so far as I can learn, none have been found. Mr. Robt. Harvie has found tellurides in similar deposits at Opasatica Lake, Quebec, which he described in a paper in vol. xiv., pp. 164-170.

†F. C. Lincoln, in his paper on "Certain Natural Associations of Gold," after collecting and analyzing 585 recorded occurrences of gold in veins, says, on p. 286, Econ. Geol., April-May, 1911: "The most common metallic minerals occurring with gold in veins, in the order of their numerical importance are—pyrite, galenite, chalcopyrite, sphalerite, arsenopyrite, etilnite, tetrohedrite, argentite, pyrrhotite and silver. The non-metallic minerals are quartz, calcite and barite."

‡C. W. Knight describes in Notes on Bureau of Mines Map, veins on Miller-Middleton claims, having the composition of granite. See also A. G. Burrows' report, p. 19, 1911. J. Stansfield describes occurrence of feldspar in ore from Vipond Mine.

The quartz in some cases has a ribboned appearance due to the presence of dark coloured aggregates of minerals in minute crevices. The aggregates are made up chiefly of pyrite, sericite, carbonates, chlorite and a brown serpentinous substance of unknown composition. The same minerals also occur irregularly through white quartz giving some of the ore a spotted appearance. From the mode of occurrence of these dark coloured aggregates it seems likely that they were formed after the quartz had been crushed. From the occurrence of gold with these aggregates it seems likely that some of the metal has been deposited much later than the quartz.

The quartz is made up partly of large grains (see microphotos 1b, 2b and 3b), which probably represent the form in which it was originally deposited; but largely of very small grains (see microphotos 4b, 8b and 9b), which have evidently been formed by subsequent crushing or granulation. The individual grains in almost all cases when examined in polarized light exhibit evidence of strains. In the specimens examined microscopically most of the gold is in parts of the quartz which have been granulated.

The quartz contains very numerous fluid inclusions* (see gray appearance of quartz in all the microphotos) and was therefore probably deposited from a hot solution at considerable depth. Such inclusions are very common in quartz which is known to have been deposited hot, as in the case of the formation of such rocks as granite. The mere presence of inclusions is not of itself sufficient evidence of high temperature and depth, for there is reason to believe that some inclusions have been formed after the solidification of the quartz. The inclusions are frequently arranged in rows (see microphotos 3a and 6a), and some of these run through adjacent quartz grains without interruption. Many of the rows, however, ter-

*The composition of the inclusions has not been determined. Water is probably the chief constituent. The nature of fluid inclusions in certain minerals, and their probable origin, is discussed by A. C. Sorby and P. J. Butler in Proceedings of the Royal Society, vol. xvii., pp. 291-302, and by G. H. Hawes and A. W. Wright in American Journal of Science, pp. 203-216. The writer tested some Porcupine ores for CO_2 in manner described by these writers (heating over 31° C., the critical point) with negative results.

minate at the quartz grain boundary, and there appear to be fewer inclusions in the granulated than in the original quartz grains.

There are other characters which suggest that the solutions were hot and probably partly of magmatic origin. Pyrite is commonly formed from hot alkaline solutions.* Tourmaline is frequently and scheelite occasionally present, and these two minerals are generally found in what are believed to be acid differentiation products. Sericite, so abundant in the wall rocks, is a mineral that is generally thought to be formed by hot solutions.†

From optical examination it seems likely that the gold, pyrite and quartz were originally deposited from the same solution and that the solution was hot. Subsequently the deposits were crushed and fractured and secondary minerals were deposited in the fractures. (See microphoto 6a.) It is probable that some of the gold was dissolved and re-deposited in other parts of the vein. It appears especially probable that the coarse grains were formed by such a secondary process.

Some writers‡ have interpreted their observations to indicate that the fissures were first filled with barren quartz and that the gold was introduced later. It is of course possible that such was the case; but I can find no necessity for such an assumption and hence prefer the simpler hypothesis. The constant occurrence of quartz and pyrite with the gold and the paucity of gold in those enclosing rocks in which quartz and pyrite are not abundant, seems sufficient evidence for the assumption of a common origin for the three minerals. Gold, quartz and pyrite were probably deposited together, and, so far as I am aware, there is a lack of evidence that gold-bearing quartz has been introduced after the first filling of the fissures.

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*See Allen, Crenshaw, Johnson and Larsen on "The Mineral Sulphides of Iron," Am. Jour. Sci. Mar., 1912, pp. 191-193.

†See Kirk, "Mineralization in Copper Veins at Butte, Montana," Econ. Geol. Jour., Jan. 1912, pp. 55-58.

‡L. V. Huntoon, "Character of Ore Deposit and Probable Milling Methods at Porcupine," C. M. J., Dec. 15, 1911, p. 812.

Subsequent solution and redeposition of some of the constituents of the primary filling and of the country rocks would account for the phenomena observed.

Characters of the Gold Ore Determined by Assays.—Assays have shown that the gold* is not regularly distributed through the quartz, but, as is commonly the case, it is chiefly in parts referred to as ore shoots. The ore is fairly high grade; but owing to the difficulty in distinguishing it from waste or mining it separately when distinction is possible, it is not improbable that the run of mine ore in some cases will be more properly referred to as low-grade. In the high-grade ore shoots the values have been found to be very irregularly distributed.

The gold is chiefly confined to the quartz veins or masses† The country rock in some cases contains pay values, but so far as I can learn there has not yet been found any important body of ore in rock that is not penetrated with quartz. The constant association of gold and quartz indicates clearly a common origin.

Assays show that the gold is chiefly in parts of the quartz near wall rock or pieces of enclosed rock, and especially in parts of the quartz that have been crushed. Most of the gold occurs with pyrite and non-pyritic quartz in the same deposit is commonly barren.

At the Hollinger it has been found‡ that the occurrence of visible gold does not necessarily mean payable values, and that quartz streaked with fine lines of pyrite in the cleavage is generally more consistent in gold values than the clear masses carrying occasional spectacular showings. Mr. Robbins found the main vein to present an unbroken ore shoot for over 1,000 feet horizontally, to be 2 ft. to 20 ft. wide, and to be usually richer in the wide portions. The occurrence of galena

*An assay of bullion from stamp mill treatment quoted by E. M. Flynn in H. P. Davis' Handbook of the Porcupine District, shows 1.08 oz. gold and 0.12 oz. silver per ton ore, indicating the percentage of fine gold to be 90.

†Gold has frequently been found in schists penetrated by quartz stringers. Such occurrences are described by P. A. Robbins in "The Hollinger Annual Report," p. 10, and by G. W. Thompson in an article on "Drilling at Pearl Lake Mine," Can. Min. Jour., April 1, 1912, p. 239.

‡P. A. Robbins' Annual Report Hollinger Gfiold Mines, Jan. 1, 1912.

was found to portend rich gold values and to a lesser degree the occurrence of sphalerite proved to indicate gold values. Large, blocky crystals of pyrite are usually attended by low values in gold, while finely crystalline pyrite occurs with relatively higher values.

It seems likely that the spectacular gold has formed by the growth of some gold grains at the expense of others in the immediate vicinity, and consequently much of the quartz near coarse gold is practically barren. The occurrence of gold with the poorly crystallized small grains of pyrite indicates that the deposition of the gold took place under conditions which were very unfavourable for the crystal growth. It is likely that the auriferous pyrite was deposited much more quickly than the non-auriferous pyrite. The different degrees of crystallization may have been due to rapid solidification from a hot solution in one case and slow growth from more gradual cooling or removal of solvents in the other. Evidently the conditions favourable to growth of large pyrite crystals were also favourable for the formation of coarse gold grains. Both are probably the result of redeposition under conditions quite different to those which obtained in the first deposition. The deposition in both cases, however, was probably at depth and from hot alkaline solutions.

The irregular distribution of the fine gold indicates that in the primary deposition there was a tendency for the gold and pyrite to segregate somewhat from the main mass of silica. There is no good reason to suppose that the contemporaneous deposition of gold, pyrite and quartz would result in very uniform distribution of the gold throughout the whole mass of quartz. The most favourable place for deposition of gold was evidently the vicinity of enclosing or enclosed rock.

Characters of the Gold Ores Determined by Mechanical and Chemical Treatment.—While all the ores are examined optically, it is done for the most part in a rather cursory manner, and by those who do not record their observations. The samples examined microscopically are very small and may not be representative. The samples assayed are much more numerous and larger, and we have found that the assays are in a

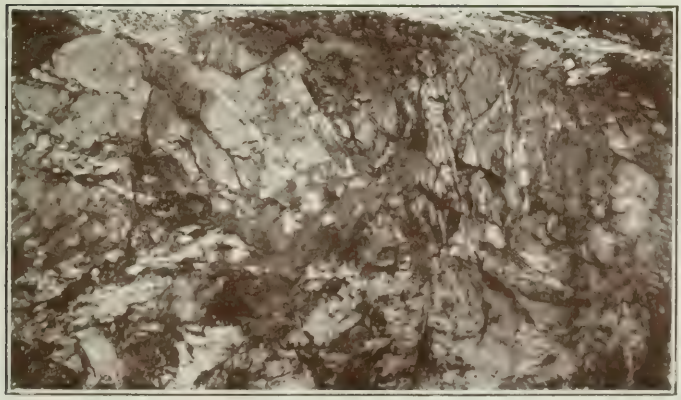
general way such as might be expected from the ores described from optical tests alone. A consideration of the results obtained by milling and cyaniding should show whether the ore thus tested was similar to that examined microscopically and to the samples assayed.

Tests on the ores of the Dome and Hollinger Mines show them to be very free milling. Much of the gold is in clean quartz, from which it is very readily freed by crushing and then readily recovered by amalgamation. The remainder is rather readily recovered by regrinding and amalgamation, followed by cyanide treatment.

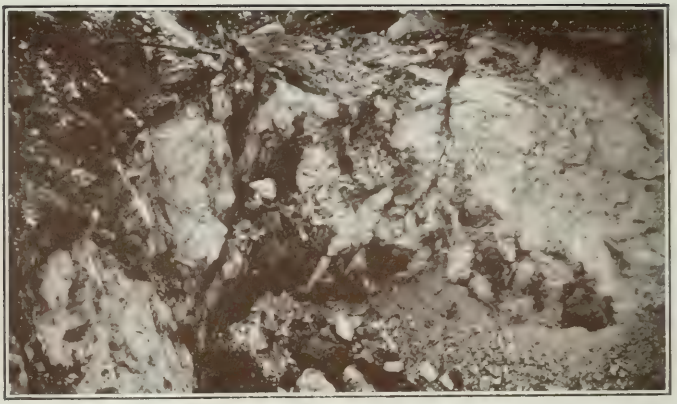
The results obtained in testing Dome Mine ore have been published in The Canadian Mining Journal, Feb. 15, 1911, pp. 126-127. The ore was at first considered to be an ideal concentrating ore. The gold being closely associated with the pyrite, a high-grade concentrate was obtained. The tailings, however, were sufficiently valuable to warrant cyaniding. By regrinding the concentrate it was found that a large percentage of the gold could be recovered by amalgamation. By grinding to 90 per cent. through a 200-mesh screen 84 per cent. of the gold was recovered by amalgamation. The ore tested was found particularly free from cyanides, the only difficulty arising from the presence of a small amount of carbonaceous material, which made it necessary to lengthen the period of agitation to avoid a secondary precipitation. Mr. C. W. Merrill, designer of the plant, has recently been quoted as saying that the total recovery is expected to be not less than 95 per cent.

The results obtained in testing Hollinger Mine ore have been published in the first annual report, January, 1912. Tests for extraction were run upon a sample containing 2.1 oz. per ton. This sample was found to contain 4.86 per cent of concentrates, and the concentrates contained 82.6 per cent. of the gold contents of the ore. (Shows intimate association of gold with pyrite, for very fine gold in clear quartz would not be in concentrate.) Following concentration the residue was leached with cyanide solutions, and after 114 hours' treatment it was

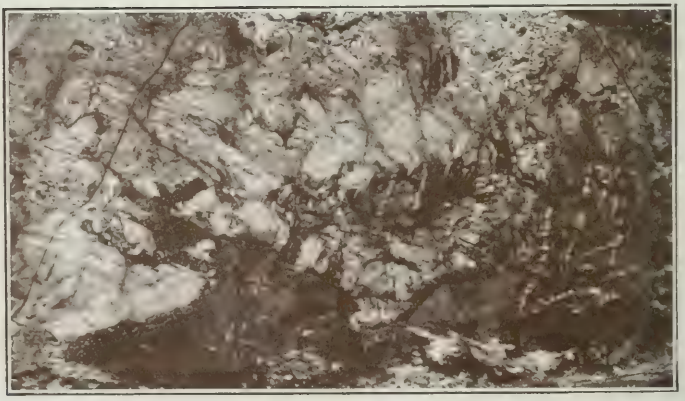
Gold quartz, Dome Mine, Porcupine, Ont.



Gold quartz, open pit, Dome Mine, Porcupine, Ont.



Gold quartz, Dome Mine, Porcupine, Ont.



Gold quartz, open pit, Dome Mine, Porcupine, Ont.

Open pits at Dome Mine.

Gold quartz veins, Dome Mine, Porcupine, Ont.

found that cyaniding had extracted approximately 60 per cent. of the remaining values.

In the second test the ore was ground in the mill to pass 120-mesh and split into two lots. The first lot was concentrated, the concentrates removed and the impoverished residue agitated by air in cyanide solution. After 34½ hours' treatment the extraction by cyaniding of values contained in residues was found to be 95.1 per cent. and the combined extraction by concentration and cyaniding was 99.56 per cent of the total original gold contents of the sample. The second lot of finely crushed ore was concentrated, but after pan-amalgamation of the concentrates they were returned to the agitator to be treated with the tailings from the concentrator. The combined extraction by this method was practically 100 per cent., as the residue after 36 hours of cyanide treatment carried only a trace of gold. In these tests the concentrates amounted to approximately 37 per cent. of the total ore treated, and the consumption of cyanide was in the neighbourhood of two pounds per ton. Mr. Robbins states that the net result of the tests on Hollinger Mine ore was to show the necessity for fine grinding and also the advisability of extracting the concentrates for separate treatment.

Results of tests on ore from the Vipond Mine are given by E. M. Flynn in H. P. Davis' Handbook of the Porcupine Gold District, 1911, pp. 38-39. The ore was stamped to pass 20-mesh, passed over amalgamation plates, the pulp from the plates concentrated on Wilfley tables and the tailings separated into sand and slime. The sand was leached for 72 hours with 0.2 per cent. KCN solution. The recovery on the plates was 73.46 per cent., on the tables 14.06 per cent., and by cyanidation of sand tailing 3.20 per cent. Further cyanide tests proved that the extraction could be considerably increased by fine grinding of the sands. It was found that concentrate (25-1) from high-grade ore ($100 to $200 per ton) contains about the same gold as that from lower-grade ore ($20 to $30). The concentrate in each case was rather low-grade ($50 to $150), indicating that comparatively little gold is enclosed in pyrite.

From the intimate association of gold with pyrite it is evident that on coarse grinding nearly all the microscopically visible gold would be contained in a concentrate comprising a very small part of the ore. Mr. Kirby's test, 82.6 per cent. of the total gold to be in concentrate comprising 4.86 per cent. of the ore.

From the microscopically visible gold enclosed in clear quartz and other light minerals it is evident that many of the finer particles of gold would not be reached by cyanide solution unless finely ground. Mr. Kirby's test on the residue shows 40 per cent. unrecovered, and his screen test shows 61 per cent. of these values to be in sand coarser than 60-mesh.

Most of the microscopically visible gold associated with pyrite is not completely enclosed in pyrite or even in actual contact with it, and it is evident that if finely ground it would be very readily amalgamated. All the mill tests show this to be the case.

From microscopic examination it is known that gold occurs in very minute particles, and it seems not unlikely that the invisible gold is present also as the native metal, but in particles of sub-microscopic size. The mill tests show results which would be expected if such very fine particles of native gold were present, and there seems no good reason to assume that the gold in pyrite is other than a mechanical mixture. There is then no evidence of the former existence of the gold in some mineral other than the native metal, and it is safe to conclude that part at least is in the form in which it was originally deposited.

Characters of the Wall Rocks.—The wall rocks are of several types, originally quite different, but by secondary changes having in common a high content of sericite, ferrodolomite and quartz. The wall rock of most of the ore bodies is a gray sericite-carbonate-quartz schist that was probably originally a quartz porphyry. Other wall rocks include basalt, porphyrite, conglomerate and gray slate. These are all much altered, and near the veins there is usually much pyrite present. It is commonly in well-formed cubical crystals. As a rule the amount of pyrite in the rocks is much greater than in the veins.

The characters which are common to all the wall rocks are of secondary* origin. It is evident that similar solutions penetrated and altered the different rocks and replaced some of the constituents by sericite, ferrodolomite, calcite, quartz and pyrite.

These minerals are especially abundant in the immediate vicinity of the quartz veins, and it is reasonable to suppose that they came through the fissures† which were subsequently filled by gold quartz. It is furthermore probable that the solutions came from the same source as the gold quartz.

Conclusion as to Origin of the Deposits.—We have in the Porcupine District pyritic gold quartz deposits enclosed in rocks characterized by an abundance of ferrodolomite, sericite and pyrite. The nature of the ore and the wall rock‡ sug-

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*Microscopic descriptions by C. W. Knight and A. G. Burrows of some of the wall rocks are given in the reports published by the Ontario Bureau of Mines. The ores and wall rocks of the Vipond Mine were described by J. Stansfield in Canadian Mining Journal, Feb. 15, 1911, pp. 109-115. The ores and wall rocks at the Dome, Hollinger and Rea Mines were described by R. E. Hore in a paper submitted to this Institute in 1911, pp. 171-184, vol. xiv.

†Remarkably similar characters were found by Lindgren in wallrocks of California gold quartz deposits. He gives descriptions and chemical analyses of these rocks in a paper on "Metasomatic Processes in Fissure Veins." Genesis of Ore Deposits read at Washington meeting (1900) A. I. M. E., and republished on pp. 586-588. In another paper entitled "Metasomatic Processes in the Gold Deposits of Western Australia," Econ. Geol. Vol. 1, 1905, pp. 530-544, Mr. Lindgren describes similar features of the Galgoorlie gold fields, and concludes that the remarkable similarity of the rock alteration at the Mother Lode (California) mines to that at Kalgoorlie gold fields, and concludes that the remarkable similarity of the bearing veins from solutions practically identical in their general composition.

‡In another article, Bull. Geol. Sur., 1895, p. 233, speaking of these similar carbonate wall rocks Mr. Lindgren says: "This action upon the adjoining country rock is in itself, to my mind, the strongest possible evidence against the application of lateral secretion in its narrow sense to these veins. It appears to completely refute the theory of the veins being formed by percolating surface matters, and prove the existence of an agency active in the fissures and gradually extending outward."

‡In an article on geological features of the gold production of North America, published in transactions of A. I. M. E., vol. 33, 1903, pp. 790-845, Mr. Lindgren states: "The Mesozoic gold quartz veins of the Pacific Coast are practically identical in character from Lower California to Alaska, and, moreover, closely related in character to the far older (pre-Cambrian) Appalachian belt. Where the wall rocks are easily altered, they contain abundant calcite and other carbonates, besides much sericite. This points, without doubt, to a remarkable constancy throughout the whole province

gests that the gold was introduced into the fissures along with the chief constituents of the minerals mentioned. The solution* which contained the gold probably contained also in some form iron, sulphur, silica, potassium† and carbon dioxide.‡ From the solution practically all the potassium and carbon dioxide escaped into the wall rocks and aided in the formation of sericite and ferrodolomite. Part of the iron and sulphur also escaped into the wall rocks and there formed pyrite crystals and contributed iron to the formation of ferrodolomite. Part of the iron and sulphur and nearly all of the gold and silica was deposited in the fissures themselves. It appears that the walls were more readily penetrated by some constituents than by the others, and in this way much of the water, carbon dioxide, potassium†, sulphur and iron escaped. In proportion as these constituents escaped the solubility of the gold in the

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in the composition of the mineral waters which formed the veins. They were manifestly distinguished by an abundance of alkaline carbonate.'' Deposits of this type, with derived placers, are the chief source of the gold of North America. Mr. Lindgren states that up to 1900 they had produced $1,719,000,000. The whole production of the continent for the same period was $2,869,000,000. Placers contributed by far the greater proportion of this total. According to C. G. Yale, writing in March, 1912, bulletin of A. I. M. E., the placer mines of California are at present producing 45.09% and the quartz mines 54.91%.

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*For discussion of experiments by Doelter, Liversidge, Yleston, Becker and Skey on solability of gold in solutions containing such constituents see MacLaren Gold, pp. 105-107, and Lindgren, Characteristic Features of California Gold Quartz Veins, Bull. Geol. Soc. Am., 1895, pp. 237-238, and F. W. Clark, Data of Geochemistry, U.S.G.E., Bull. No. 491, 1911, pp. 617-618.

†Potassium, one of the chief constituents of sericite would be abundantly present in feldspars in some of the wall rocks like quartz porphyry, and doubtless much of the sericite derived its constituents from the wall rocks. Sericite, however, is also an abundant constituent of wall rocks such as basalt which probably contained little potassium, and it is probable that some was introduced from the solutions carrying the other constituents mentioned.

†There were probably numerous other constituents, some of them now present in accessory minerals mentioned above. For simplicity their presence is not discussed here. There may have been important factors in the formation of the gold deposits, but to the writer it seems that their influence was very subordinate.

‡The very common of abundant carbon dioxide or carbonates in thermal springs is emphasized by F. Prospeny in his treatice on the Genesis of Ore Deposits, pp. 42-44, 2nd edit. A. I. M. E., 1902. In the same volume on pp. 221-222, Mr. T. A. Rickard describes the Huraki or Thames gold field

remaining solution would be decreased and the deposition therefore aided by removal of solvent as well as by lowering of temperature. The pyrite first formed in the veins was comparatively poorly crystallized and was probably formed quickly. The pyrite in the wall rocks and some pyrite in the veins that is probably of secondary origin is in well-formed crystals and evidently formed slower or at least under some more favourable conditions than did the original auriferous pyrite of the quartz veins. The gold and pyrite were not evenly distributed originally. Evidently in the first crystallization they tended to segregate here and there, and the especially favourable place for deposition was near the walls or around masses of enclosed rock.

After the filling of the fissures with quartz, gold and pyrite, the veins were shattered and the quartz granules strained or crushed. In the crushed zones a secondary set of minerals, including sericite, chlorite, calcite, ferrodolomite and pyrite and some gold were deposited. These probably originated in the vein and wall rocks. Much of the gold thus formed is in coarse grains, which probably grew by slow accretion of small particles by a process continued over a long period. It is probable that this coarse gold grew at the expense of the fine gold contained in the vein matter in its immediate neighbourhood, thus leaving much very low-grade quartz in the vicinity of the spectacular specimens. The coarse gold to which a secondary origin is here attributed, while showy, is usually quite subordinate in amount to the fine gold, much of which may well be still in the form in which it was first deposited with the pyrite and quartz. Some fine gold, however, is probably secondary, and there are cases in which the amount of secondary gold is greater than the amount of primary.

There is nothing to indicate that the character of the deposits has to any considerable degree been changed since the

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in the North Island of New Zealand. He states that at the Thames the escape of carbon dioxide has often caused a temporary cessation of work in the mines. He concludes that "the deposition of the gold and its associated minerals had followed certain lines of altered country rock which had been exposed to the effects of dying but lingering solfataric agencies.

glaciers cleaned away the surface rocks, and there is therefore no reason for believing that the ore will show any appreciable dependence on the present surface. The secondary changes which have taken place are not surface alterations, but rather of a character which might be expected to take place at considerable depth.

From the information at present available, therefore, no remarkable change in the character of the ore with increasing depth is to be expected. It is also likely that in some cases at least similar ore shoots exist below those exposed. To what depth the individual ore shoots exposed at surface extend cannot be predicted, but unequal depths may be expected. Of those which had originally somewhat similar vertical dimensions, it is probable that some had lost very largely and others comparatively little by erosion. A first approximation is therefore obtained by assuming that one-half has been eroded. If we assume also that the vertical and lateral dimensions were originally somewhat nearly the same, our best guess, where no development work has been done, is that the ore shoot now extends to a depth equal to one-half the horizontal length. It is quite possible and, from the geological evidence, very probable that some of the deposits continue to great depth.

RECENT UNDERGROUND DEVELOPMENT WORK AT COBALT.

By Cyril W. Knight, Toronto.

The geology of Cobalt is well known chiefly through the reports of Willet G. Miller, the provincial geologist for the province of Ontario. The present paper makes no attempt to add anything fundamental to the memoirs of Dr. Miller, but is merely a brief summary of certain recent underground developments.*

It will be recalled by those familiar with the area that the rocks are of pre-Cambrian age, and that a series of conglomerates, greywackes and greywacke-slates, known as the Cobalt series, rest unconformably on a greenstone complex correlated with the Keewatin series. Both series have been invaded by a great mass of diabase which, as early as 1904, was recognized by Dr. Miller to occur in a sill-like or laccolitic form. It is with the occurrence of the sill that this paper has mostly to do, since the underground development, which has been accomplished during the last four or five years, has added useful information to our knowledge of it. At the request of Dr. Miller the writer compiled ten cross-sections which accompany the fourth edition of the report on Cobalt in Part II. of the Nineteenth Report of the Bureau of Mines of Ontario. Copies of these cross-sections, together with a map of Cobalt (scale 800 feet to an inch) showing their position, also accompany the present paper. The sections show the sill to be resting sometimes in an almost horizontal attitude, as at Diabase mountain (plate II, section G H), and sometimes in more or less steeply inclined positions, particularly in the Kerr lake area. As yet there is not sufficient data to definitely determine its thickness, but an approximation to the

*Notes on the Cobalt Area, by W. G. Miller, Eng. and Min. Journal, Sept. 30th, 1911. This paper is the most recent summary of the Geology and Ore Deposits of Cobalt.

truth may be obtained at the O'Brien and Colonial mines, the top of the sill having been preserved at the latter property by a capping of Keewatin greenstone. Assuming that the top and bottom planes of the sill are roughly parallel, and that there are not any important faults between the two properties, the sill would have a thickness of five or six hundred feet. (Section A B C, plate I.) Between Kerr Lake and the Temiskaming Mine it is possible that it may be much thicker than this.

Before mining operations may be said to have properly begun the presence of important faults could not be proved, though in his third edition of the report on Cobalt, Dr. Miller said: "There may thus be a fault parallel with the main axis of Cobalt Lake." The underground work at the La Rose, Cobalt Lake and McKinley-Darragh mines has amply demonstrated the presence of this fault, and has also proved that there is a vertical displacement of 233 feet at the La Rose and at least 250 feet at the McKinley-Darragh (February, 1912). But the throw at the latter property is believed to be greater than this—possibly 400 feet or more. The fault, the plane of which inclines to the east at an angle of 60 or 70 degrees, is a reverse one which carried down the rocks on the west side of the lake. (See sections Y Z and W X.) Minor displacements also occur at these properties.

An important fault probably occurs parallel with the longer axis of Kerr Lake; but sufficient work has not been done to prove its presence, although there are well defined fault planes known. One of these occurs in the diabase in a drift on the first level of the Crown Reserve, 540 feet north of the main shaft. It dips 15 to 20 degrees to the north, but the direction of movement is not known.

The lower half of plate IV shows an ideal restoration of the rocks and veins at Cobalt. The veins occupy three positions relative to the diabase sill:—(1) Above the sill, as, for example, the Temiskaming, the Beaver and the Nova Scotia; (2) in the sill itself, examples of this class being found at the Kerr Lake, Bailey, O'Brien, etc.; (3) below the diabase, as at the Crown Reserve, Lawson, vein 26 on the Nipissing, etc. The greater

proportion of the silver mined at Cobalt at one time occurred below the sill, prior to the erosion of the latter.

There are small parts of the cross-sections which have not been coloured on account of the lack of data; as, for instance, the rocks between the Crown Reserve and the Silver Leaf North Shaft (Plates II and IV), and also the part below the McKinley-Darragh shaft (Plate VI, section W X). The delineation of other parts of the sections must be considered, and will remain, more or less arbitrary until shafts and drifts have been sunk and run at critical points. Nevertheless, it was thought advisable to issue the sections as they now stand, rather than to wait many months or years for the necessary data.

DISCUSSION.

DR. BARLOW:—I have listened with a great deal of interest and pleasure to Mr. Knight's explanation of these cross-sections, which show in such a complete and satisfactory manner the results of the recent underground development work at Cobalt, especially as regards the relations and thickness of the diabase sill. As early as 1899,* the sill-like character of much of this newer diabase was pointed out by me, and later in 1904 by Dr. G. A. Young, working under my instructions in the Timigami district, gives the following description of its mode of occurrence.† "Areas of diabase occur throughout the district and it appears tolerably certain that all of these are parts of a once continuous sill." . . The diabase is frequently found capping the slate and the line of contact is seen to follow the folds of the slate formation. At one locality a sheet-like area of diabase passes gradually into a dyke-like mass dipping under the granite; the diabase is also found dipping on all sides under hills of granite and syenite." The geological map illustrative of this work shows this sill of newer diabase to be nearly 500 feet

*Ann. Rep. Geol. Surv. Can., Vol. B, 1897, p. 105.
†Surv. Rep. Geol. Surv. Can., 1904, p. 198.

thick* at one locality where it was possible to be obtained, a rather close approximation to the truth. Many of the sections of diabase were obtained which measured from 240-260 feet in thickness, and it was inferred from the coarseness of texture that only about one-half of the original thickness of the sill was represented at the localities examined. I would like to ask Mr. Knight at what point or place this intrusion of diabase came up before it spread out in approximate horizontal position. In the region to the southeast of the northeast arm of Timigami Lake a dyke about 650 feet wide between Herridge and Christy Lakes, is apparently the principal feeder. It has always seemed to me that in the Cobalt district the real deep-seated source was in the area to the south of Kerr Lake.

Mr. Knight:—I do not think we have information to show exactly where the diabase did come up at Cobalt. Diabase and closely related rocks frequently occur as sills, as shown by Lawson's report on the Port Arthur district, and by Dr. Barlow's observations in the Timiskaming region outside of Cobalt. The Great Whin sill of the north of England is a famous example. It is traceable for a distance of 80 miles, and has a total area, perhaps, of not less than 1,000 square miles. The rock, like that of the Cobalt sill, is essentially quartz-diabase.

Mr. Tyrrell:—The light which Mr. Knight has thrown on the structure of the country in his interesting paper and in his geological sections will be of great assistance to anyone who is concerned in the study of the origin and occurrence of the silver-bearing veins in the Cobalt camp.

I would like to emphasize what I said at the Annual Meeting of this Institute in Toronto in 1907,† in the discussion of a paper by Dr. C. R. Van Hise on "The Ore Deposits of the Cobalt District, Ontario," and also in a paper which I wrote for the *Canadian Mining Journal*‡ in the same year. I then drew attention to the fact that the ore-bearing solutions would appear to have come up at the latest stage of the diabase intrusion, probably

*Geol. map of the area between Timigami and Rabbit Lakes, by A. E. Barlow and G. A. Young (No. 944).

†Jour. Can. Min. Inst., Vol. X, 1907, p. 58.

‡Vein Formation at Cobalt, Ont., by J. B. Tyrrell, Can. Min. Jour., August 1st, 1907, pp. 301-3.

through the same vent by which the diabase itself had risen, and that they had spread out laterally beneath the relatively impervious diabase sill and had descended into the fissures which had been formed by the subsequent cooling of the rocks beneath the diabase. In this way the bottom plane of the diabase was the plane or zone from which the silver-bearing solutions had been immediately and finally derived, and consequently most of the veins in the district had been filled from above rather than below, although this downward filling was part of the deep-seated and not of the vadose circulation. "The fissures would be widest and most extensive close to the diabase and would gradually pinch out and disappear at a distance from (below) it. This distance must, of course, be computed where the diabase was originally, before any of it was removed by erosion."

(Referring to Mr. Knight's general section across the district, Plate IV). Beginning at the western end of this section we must recognize that this diabase sill certainly did not terminate where it terminates now, and that its western end was not the extreme end of the sill in that direction when it was formed, but that the sill must have covered a considerable stretch of the country to the west, and that both it and the rocks which rested on it, if there were such rocks, have long since been eroded away. Following westward the rise of the bottom of the sill as it is known to occur beneath Peterson Lake we see that it must have rested on the hills occupied by the eastern portion of the Nipissing property, and that the rich veins on this property were therefore formed close to the base of the diabase, just as the silver-bearing veins beneath Peterson Lake are found to cling to the bottom of the diabase.

Where the Huronian conglomerates and schists immediately underlay the diabase sill they favoured the formation of the silver-bearing veins, but where the Huronian was not present and the Keewatin rocks immediately underlay the diabase the silver-bearing solutions descended into these rocks and formed veins in them.

Dr. Barlow:—Might you not, then, reasonably expect to get silver in the Keewatin rocks of the vicinity of Sasaginaga Lake?

Mr. Tyrrell:—As you proceed farther and farther from where the diabase at present occurs you necessarily become more and more uncertain as to whether it flowed over that particular district or not and, even if it flowed over or covered it and has now been eroded away, whether a considerable depth of the rocks which originally underlay it has not also been removed by erosive agencies. If, for instance, the diabase and two or three hundred feet of the rocks underlying it have been removed from a certain district it is quite possible that rich silver-bearing veins may have been present, and that they may have been entirely removed.

Dr. Barlow:—That is just the point I wish to have brought clearly before the meeting, because certain people have an abiding faith in the Sasaginaga and Clear Lake district on account of its proximity in a horizontal direction to some of the richest mines of Cobalt.

Mr. Tyrrell:—Near the eastern end of Mr. Knight's section we see that the diabase sill dips fairly steeply beneath the underlying Keewatin rocks. The Temiskaming Mine is located in this part of the country and is underlain by the Keewatin, which is again underlain by the sill of diabase. In this case the silver-bearing solutions which gave rise to the mineral veins would seem to have proceeded upwards from the diabase rather than downwards from it. As a general rule, I think that the bottom plane of the diabase was much the more likely zone or plane to carry enriching solutions, but in this case the enrichment would come from the top of the sill.

In the Gowganda district most of the veins which carry silver are in the diabase itself and, unfortunately, we know very little about the character of the veins in the rocks immediately underlying it.

Dr. Barlow:—The Temiskaming is an exceptional mine, because the shaft has penetrated to such a great depth in the Keewatin formation. I have, however, seen some specimens which resemble the basic edge of the diabase sill, so that it is possible that these may represent apophyses of the main sill, which will be encountered in sinking the shaft further.

Mr. Knight:—The Temiskaming shaft is down about 450 feet, and at that point I have no doubt that it is in Keewatin.

DR. BARLOW:—It is often very difficult to tell the difference between certain portions of the newer diabase and some of the more massive phases of the older Keewatin diabase. It seems a very gratifying feature of the development of the Cobalt camp that the early expressed ideas of the geologists have been amply sustained by the subsequent development work.

NOTICE

The maps to accompany Mr. C. W. Knight's paper, "Recent Underground Development Work at Cobalt," were supplied to members with No. 18 of the Quarterly Bulletin of the Institute, (February, 1912). Additional copies will be furnished, however, upon request.

THE PROBABLE TOTAL PRODUCTION OF SILVER FROM THE COBALT DISTRICT.

By G. R. Mickle.

(*Cobalt Branch Meeting, May* 1st, 1912.)

The Cobalt district is perhaps the most interesting one that any of us will ever see, the fascination being due to the great number and richness of the veins and their erratic distribution over the productive area.

As the silver is derived from a large number of veins and over 80 per cent. of it is obtained from one geological formation the limits of which are small and are now generally definitely known, a mode of reasoning can be employed in calculating the probable production of silver, which, as far as the writer is aware, could not be used in any other metal mining district.

In the following estimate certain arbitrary standards are adopted for the purpose of making definite calculations. Veins that have a certain minimum yield in ounces are called productive. It is obvious that the line must be drawn somewhere, it would be absurd to consider a vein that only yielded a few sacks of ore as productive, and as it was desirable to compare this district with others where any vein with only a trifling yield would probably be lost in the records, the minimum output of a productive vein is assumed in the following calculations as 75,000 ounces.

Up to July, 1911, there appeared to be 111 veins that could be considered productive on this basis; these were distributed among the different geological formations as follows:—

Huronian	86	veins or	77.5%
Diabase	12	" "	10.8%
Keewatin	13	" "	11.7%
	111	" "	100.0%

If the same vein extended into two different formations it was credited to the one out of which the greater part of the silver was obtained. In 1907 at the same time of the year the writer gave the distribution as*:—

Huronian	53	veins or	80.3%
Diabase	7	" "	10.6%
Keewatin	6	" "	9.1%
	66	" "	100.0%

Four years of energetic and skilful prospecting has not altered the relative number of veins in the different formations. The productivity, however, of the veins in these different rocks is not the same. Up to the present (*i.e.*, July, 1911) the yield from the diabase has been approximately 7.55 million oz. from 12 veins or 629,000 per vein, or 7 per cent. of the total production. The Keewatin with 13 veins has produced 11.7 million oz. or nearly 1 million per vein, or 10.85 per cent. of the total. This includes whatever silver was obtained in the Keewatin from veins classed as Huronian but extending into the Keewatin. The balance, or 88.55 million oz., has been derived from the Huronian with 86 veins, or a little over 1 million oz. per vein and over 82 per cent. of the total production. According to the writer's estimate, when all veins at present known are exhausted, the Huronian veins will have produced slightly under 2 million oz. per vein, or 86.6 of the total, leaving 13.4 per cent. to be distributed between the diabase and Keewatin. It is plain, therefore, if the amount of silver in the Huronian veins can be approximately determined, even a serious error in the estimate of the other veins cannot vitiate the result very much.

*Jour. C. M. I. Vol. XIII.

In making this calculation it appeared that the most feasible plan was to form an estimate of the probable amount of silver in the veins already known on each property which was worked as a unit, rather than to attempt to keep the production of each vein by itself, the necessary information being naturally collected in this way. Then in any given case the production from any particular vein is known approximately, its relative weight as a source of silver, and the extent to which the silver in each vein is exhausted can be estimated by inspection of the workings and plans and knowledge of the past performance, multiplying one by the other gives the percentage of the total silver taken from the property in question due to the operations on each vein, and by addition of all these amounts the total percentage of silver mined can be ascertained. For example, suppose a property has six veins and the veins have the relative weights given below and are exhausted to the extent indicated, the calculation is made thus:-

No. of Vein	Estimate of Percentage of Total Silver on each property (Relative weight.)	Estimated % Silver gone	% of Total gone
1	30	40	12.0
2	20	30	6.0
3	15	50	7.5
4	10	50	5.0
5	15	60	9.0
6	10	90	9.0
	100		48.5

In this imaginary case 48.5 per cent. of the silver has been removed. The production in ounces being known for each property, the total probable production can readily be calculated. If this is done in each case and the results set down as indicated below the total probable production from the discovered veins can be obtained.

In making these estimates it was assumed in the case of the Huronian veins, unless the development work showed otherwise,

that the silver would extend down to, but not beyond, the contact with the underlying Keewatin. It can be shown that it is highly improbable that any substantial error could be made by this assumption. Out of 86 Huronian veins known up to the time the estimate was made not less than 60 of them had been explored sufficiently in this respect to prove that the quantity of silver extending into the underlying Keewatin is relatively insignificant. As these are selected at random in all parts of the district, it follows that it is very improbable that any considerable percentage of the Huronian veins will maintain their values along the dip into the Keewatin. If anyone should doubt this, let it be assumed that 10 per cent. of the Huronian veins do carry undiminished values into the Keewatin and the balance do not. Then the chance that any given Huronian vein will terminate as far as silver values are concerned at the Keewatin contact is 9 in 10, or $\frac{9}{10}$ and the chance that any two will thus terminate is $\frac{9}{10} \times \frac{9}{10} = \frac{81}{100}$; any three would give a chance of $\frac{9}{10} \times \frac{9}{10} \times \frac{9}{10} = \frac{729}{1000}$, and so on; the chance that any 60 veins selected at random will terminate at the contact is therefore $(\frac{9}{10})^{60}$, or $\frac{1}{556}$. But this thing, which has only a chance of 1 in 556, according to the hypothesis, has happened, therefore, we must conclude that 10 per cent. of the Huronian veins do not carry substantial values into the Keewatin below, and that the percentage of Huronian veins which may do so is much less than 10 per cent. and is, therefore, negligible.

In setting down the results of the estimate thus explained, the properties naturally fell into groups according to their probable production and not their relative position. The mode of calculation is indicated in skeleton form below.

Production up to July, 1911. Mill oz.		% of Silver gone.	Probable Production.	% of total Silver in District on this property.		% of total Silver gone.
Group A						
Over 10 mill oz.					69.42	
Probable production						
Group B						
5-10 mill production	103.0				14.04	
Group C						
1-5 mill production					13.74	
Group D						
Less than 1-mill production	4.8				2.80	
	107.8				100.00	56.1

It will be observed that the only estimate which is subject to error in the above calculation is the one of the percentage of silver which is exhausted. It is believed that this estimate will seldom be more than 20 per cent. from the actual truth in any case, that is, supposing that 50 per cent. of the silver in any given case has been removed, the estimate would not be less than 30 per cent. or more than 70 per cent. What effect this will have on the accuracy of the result will be seen. Taking Group A., with probable production of 69.42 per cent. of the whole, this was derived from 64 sources, that word being used in preference to vein, as there are a number of cases where the same vein is worked on different properties and constitutes a source on each. The number of sources is therefore greater than the number of veins. It is plain that, unless all, or nearly all, the errors are in the same direction, the result must be an approximation of the truth. How remote the possibility of all the estimates being too high, for instance, can be seen by calculating the number of ways in which the estimates might be made, eliminating the possibility of any given estimate being correct, then the chance that any given one is too high is 1 in 2, or $\frac{1}{2}$. there being only two possibilities and each being equally likely. The chance of all 64 estimates being too high is $\left(\frac{1}{2}\right)^{64}$, or $\frac{1}{18,446,500,003,000\ 000,000}$ This represents the chance there would be of making an error of 20% of 69.42 per cent., or 13.88 per cent. of the whole due to estimates in Group A.

Similarly Group B., with 13 sources and estimated production of 14.04% of whole, gives a chance of $\left(\frac{1}{2}\right)^{13}$, or $\frac{1}{8192}$ of making a maximum error of 2.81%. And Group C., with 43 sources and 13.74% of total production would show a chance of $\left(\frac{1}{2}\right)^{43}$, or $\frac{1}{8,796,000,000,000}$ of making an error of 2.75% of the whole. Group D., with over 14 sources and 2.80% of the total production is evidently so small that it may be neglected. The chance of being too high in all (neglecting Group D.) is the product of all these chances and is 1 in 33,388,100,-000,000,000,000,000,000,000,000,000. Evidently an impossibility.

So far the calculation only shows the practical impossibility of all the errors being in one direction; the probable error in the calculation can be found by employing the formula developed

in the Method of Least Squares and used by scientists to determine the limits of accuracy of any set of observations, viz.:—

$$*\text{Probable Error} = \pm .6745\sqrt{\frac{\Sigma v^2}{n\ (n-1)}}$$

Where Σ = sum
v = error
n = no. of observations.

In this case, then, assuming an error of 20%, as explained above, we have in the case of Group A., there being 64 observations and 64 errors:—

$$\text{Probable error} = \pm .6745\sqrt{\frac{64\times 20^2}{64\times 63}}$$

$$\text{Probable error} = \pm .6745 \times \frac{20}{\sqrt{63}}$$

$$= \pm 1.7\ \%$$

Multiplying by 69.42%, or the total percentage of the silver in this group, gives 1.18% of the whole as the probable error.

For Group B. similarly.

$$\text{Probable error} = \pm .6745\sqrt{\frac{13\ (20)^2}{13\ (12)}}$$

$$= \pm .6745 \times \frac{20}{\sqrt{12}}$$

$$= \pm 3.89\ \%$$

Multiplying by 14.04% we have $\pm$ 0.55% as the probable error in the percentage of the whole, due to incorrect estimates in Group B.

With Group C. we have:—

$$\text{Probable error} = \pm .6745\sqrt{\frac{43\ (20)^2}{43\times 42}}$$

$$= \pm 2.08\ \%$$

Multiplying by 13.74 gives $\pm$ 0.28% as probable error expressed in percentage of the whole.

*N.B.—Explanations and examples of the application of this formula to rough estimates are given in appendix. The reader is advised to study this before proceeding further.

With Group D., having not less than 14 sources and involving 2.8% of total production, probable error is ± 3.7% of 2.8%, or 0.1% of whole. Therefore total probable error is

$$1.18+0.55+0.28+0.10=\pm 2.11\%$$

If the error had been assumed as 30%, instead of 20%, it can be seen that the result would be directly proportionately greater, that is, as 30 to 20, and would be ± 3.15%, and for 40% it would be ± 4.22%; for 50% the probable error would be ± 5.27%. It is evident that an error of ± 50% is an impossibility and that 20%, as assumed, cannot be far from the truth. A reference to the probability curve, which is produced by plotting the results of any set of observations, provided the number is large enough, makes this clear. This curve has the form shown below, the horizontal ordinate being the magnitude or size of the error and the vertical representing the frequency of error. If 50% has been extracted then as something has been taken and there is something left, the estimate must be more than 0 and less than 100% and the error cannot therefore be as great as 50%. If 60% is gone the plus error must be less than 40%, and the minus error, in order to equal 50%, would require an estimate of 10%, which is inconceivable. A similar reasoning can be applied no matter what the percentage actually removed is. Hence if a 50% error is impossible there can be no vertical ordinate representing the frequency of error, and the curve must cut the horizontal line; moreover, errors of percentages near 50 must be rare and, consequently, the curve must rise slowly for a time till it comes within the range of probable errors, then the ascent will be rapid and the curve will flatten and finally pass over the point representing zero error or the truth, to the minus side, which must be similar to the plus side. If the number of observations were infinite the curve would be symmetrical and the result would be exactly correct. The resultant error is due to a departure from the symmetrical form. What undoubtedly happens is that errors would be something like this, viz.: 5% — 7% — 10% — 12% — 15%, with an occasional large one, say 40%; for this set of errors, $\Sigma\ v^2$ would equal 2143, whereas, under assumption made, it equals 2400. It is reasonable to suppose, therefore, that the estimated per-

centage of silver that has been extracted is approximately correct, if now, the amount of silver on the dumps is added to the amount produced up to the present, viz. 107.8 million ounces, the total probable production from the discovered veins is readily obtained by proportion. The writer has no data to estimate the amount of silver contained in the dumps, which is recoverable, but it cannot form more than a small percentage of the whole and, therefore, a considerable error in this cannot impair the result seriously. The silver on the dumps may be put at 5 to 10% of the total amount produced up to the present, the mean would be approximately 8 million ounces. As will be shown later this could scarcely cause an error of more than 1 to 2% of the whole from this source. Adding 8 million ounces to the 107.8 million production gives the amount of silver yielded by 56.1% of the total, by proportion, therefore, the total yield from the discovered veins should be 206.4 million ounces.

The amount of silver that will be obtained from veins yet to be discovered seems a difficult matter to calculate, still, as it can be shown, I think, that more than 80 per cent. of the existing veins are already known, even a substantial error in the estimate cannot affect the result very seriously. The amount of silver in these veins will depend, of course, in the first place, on how many there are and on the average silver content. For the number the writer has no direct proof except evidence that there probably cannot be very many more. In the paper referred to above the total number of productive veins that existed was estimated as 132, the calculation being based on an estimate of the percentage of the total area within the productive zone which was fully explored and the number of veins found at that time. In other words, the area was sampled for veins as the ore might be sampled for silver. It was hoped at the time that the error would not exceed 20% of the total. As there have been 111, or 84%, of the calculated number found already, it is evident that the plus error is less than 20%. If the distribution of the veins on the accompanying sketch is studied with reference to the Huronian, it will be seen that by far the greater number of veins are members of a cluster or group, and that there are nine such groups in all. Furthermore, that the minimum average

length of vein in any group is 200 feet; then counting all the veins, which are not more than 200 feet distant from the next one as members of a group, we have 73 veins out of the 86, or 85%, which are members of a group. If the maximum distance is taken as 400 feet, we would have 79 veins, or 92%, members of a group. That would leave 7 to 13 isolated veins. In productiveness, the average of the isolated veins is away below the general average. All the really important producing veins are members of a group. If the aggregate length of veins in the various groups shown on the plan is measured, it will be seen that it varies between 900 feet with the smallest and 6,000 feet with the largest. Now, it is evident that the greater the aggregate length of veins in any group the more likely it is that in some place one of the veins will be easily discovered; hence that it must be comparatively easy to discover some member of a group. Once a discovery is made it becomes a centre of activity for further exploratory work. The relative ease of discovery of two groups must vary directly as the aggregate length of veins composing the respective groups. Of the nine groups mentioned above and shown on plan, all but one were known in 1907. This one had the smallest aggregate length of vein and was found in 1908. Since that time, in spite of all efforts expended, no new group has been discovered. It seems probable, therefore, that all the groups that exist have been found, or, at any rate, if there are any more, they must have a small aggregate length of vein and, therefore, will not likely be of great importance. The probable minus error in the estimate, therefore, does not appear likely to exceed 10%, and we have seen already that the plus error can scarcely exceed the same amount.

To ascertain the amount of silver in the undiscovered veins, the average calculated yield of the veins already known is taken with a certain correction. In almost every set of things in nature there is likely to be one of the kind which is much greater than any one of the others, and hence there was a likelihood that some one vein would exceed any other greatly in yield. Now, if the estimate of the number is approximately correct, as appears to be the case, then 111 out of 132 have been found, or practically 5 out of 6, therefore, the chance that any given vein, and, conse-

quently, the most productive one, has been found is 5 in 6. Accordingly, to ascertain the average yield of the remaining veins, the estimated production of the largest vein was deducted from the estimated production of the whole and this amount divided by 110 to give the average. Multiplying the average thus obtained by the probable number of veins yet to be discovered, viz. 21, gives over 35 million ounces (viz. 35.5) as the production from the undiscovered veins, giving thus a probable total of silver from all sources of 242 million ounces.

Taking all the results we have the following sources of error involved in the calculation:—

1. Error in the estimate of the production of the discovered veins.
2. Error in the estimate of the number of productive veins.
3. Error due to miscounting the number of veins now known.
4. Error in estimating production of veins not yet discovered.
5. Error in estimate of recoverable silver on the dumps.
6. Error due to arbitrary assumption as to extension of certain Keewatin veins.

It is desirable to express all these errors in terms of percentages of the total production. They will be as follows:—

1. This error has been shown to be approximately $\pm$ 2% of all the silver calculated in the discovered veins, as the estimate of the production of the new veins is based on the performance of those already known, whatever error exists in that calculation will be carried throughout and therefore remains as $\pm$ 2%.

2. This is the only source of error, the extent of which is not capable of being put within narrow limits. An over-estimate of more than 10% does not seem possible as only 9 more veins are required to bring the number found within 10% of the total number calculated. On the other hand, for the reasons given above, it does not seem likely that the number eventually found will exceed by more than 10% the estimated number, keeping in mind, of course, the fact that a certain average pro-

duction is assumed in the calculation. An error here will, of course, only affect the undiscovered veins, the average production of which is taken as 10% less than that of those already known as explained above. Expressed in percentage of the whole this source may be given an error of ± 9%.

3. It is extremely difficult to count the veins. In a number of cases indicated by dotted lines in the accompanying sketch plan of veins, it is assumed that certain workings, perhaps in different properties, are on the same vein. This was done wherever the strike and general characteristics of the vein in the different workings were about the same and the distance was not too great. Subsequent work will no doubt show that in some cases veins which have been counted as one are really two, and vice versa. I put the possible error from this source at ± 5%. An error here would directly affect the estimate of the number to be found.

4. There is no direct way of arriving at the error in estimate of production of the undiscovered veins. It is clear they must be similar to those already found. If we allow a factor of safety of 10, that is, multiply the probable error of the estimate of silver in the discovered veins by 10, we would have 20%, and as there is only about 15% of the total amount calculated involved in this amount (viz., 35 million in 242), expressed in percentage of the whole we would have ± 3%.

5. For the silver on the dumps as assumed above, the error might be 1.5% of the whole; this would allow the amount to be between 4.4 and 11.6 million ounces. This error will be doubled practically.

6. In calculating the probable amount of silver in certain of the Keewatin veins where there was no evidence of exhaustion at the lowest level, an arbitrary extension was assumed of one-quarter the depth already explored; a greater extension than this would have made the dimensions of the ore body abnormal with regard to the length. If there were no extension at all or the extension were twice as great as assumed, the plus or minus error would be less than 1%; as will be seen this would make no appreciable difference in the final calculation

and is therefore disregarded. The diabase veins present no difficulty in estimation.

Summarizing we have, then, errors as follows:—

From source 1 ..... ± 2%
From source 2 ..... ± 9%
From source 3 ..... ± 5%
From source 4 ..... ± 3%
From source 5 ..... ± 3%

If all these errors were in the same direction and of the magnitude given the total would be 22%. The chance that all the errors are in the same direction is 1 in 32.

The probable error is found by a principle in the Method of Least Squares whereby the probable error of a result involving a combination of different errors is expressed by a formula, thus:—

$$\text{Probable error} = \pm \sqrt{\Sigma v^2}$$

$$= \pm \sqrt{2^2+9^2+5^2+3^2+3^2}$$

$$= \pm \sqrt{128}$$

$$= \pm 11.3\% \text{ approximately.}$$

The accompanying sketch, showing the position of the known productive veins, is reproduced as far as the geology is concerned from the map by W. G. Miller and C. W. Knight, published in 1907 by the Bureau of Mines. Where lakes, or drift-covered areas are shown on the above-mentioned map, these are eliminated and distributed among the rocks to which they probably belong. In many cases this is definitely known from underground workings. A dotted line in the border, indicating the boundaries of formations, shows where the original has been departed from. The veins are drawn approximately to scale, except that in the case of the shortest ones, say 100 feet or less long, it was found advisable to exaggerate the length on the reduced sketch plan in order to make them distinct. The position of the veins is taken in some cases from plans obtained from the

different companies and in others from my own sketches, which would be approximately correct. The numbers given on the veins in groups are for the purpose of indicating which are considered as separate ones, as a mere inspection of the plan would not show this; these numbers have no reference to those used at the various mines to designate the veins. Where there might be any doubt as to how any vein is classified the initial letters D. K. or H. are used to indicate out of which kind of rock the greater part of the production has come. In several instances the letter K. will be noticed in a Huronian area, the Huronian was so thin here that it was practically non-existent and hence could have no substantial production; the veins were, therefore, classed as Keewatin.

The smallest rectangle that will enclose all the known productive veins is outlined. The easterly boundary is drawn through Cross Lake about in the centre and from this, as a base, lines are drawn at right angles to enclose the known veins.

Appendix.

If the formula given were used to check the accuracy of measurements of precision no explanation or illustration would be required. This formula was invented about one hundred years ago by Gauss, a great astronomer and mathematical genius, and has been used by the ablest mathematicians ever since.

The term "probable error" is not a happy one and it has been suggested to use the word "uncertainty" instead. It will be noticed that as the number of observations increases the error diminishes. These observations are estimates or measurements of the same thing, or the same kind of thing, made in the same manner. The best example of this is in life insurance where they have hundreds of thousands of observations on the same kind of thing, viz., healthy males examined in a standard manner. The mortality table known as the "Actuaries" gives observations on 100,000 males. At 30 years of age, 86,292 are alive and the table gives the number of deaths each year. The "Expectation

of Life'' for a man of 30 years is given as 35 years, if he should fail to realize this he makes a minus error of so many years, and if he exceeds it he makes a plus error. The error being a departure from the arithmetic mean. Following this table, take the number stated as dying at 30 and those at 100, each make an error of 35 years, add these together and multiply by the square of 35, and so on with all the years, adding these will give Σv^2; as $n = 86292$ the formula becomes.

$$\begin{aligned} \text{p.e} &= \pm .6745\sqrt{\frac{19888856}{86292 \times 86291}} \\ &= \pm \tfrac{1}{2}\tfrac{1}{9} \text{ year.} \\ &= \pm 13 \text{ days.} \end{aligned}$$

We see, therefore, that, owing to the vast number of observations, the most certain and safest business known is based on the most uncertain thing.

To test the application of the formula to inaccurate measurements it was necessary to devise some kind of estimate which would be easily made and readily checked, accordingly two figures were constructed as shown and ten different observers asked to estimate the interior angles, no protractors or sett squares or any mechanical aid was used, the object being to have purely eye measurements which must necessarily be rough. The observers were all men with a knowledge of drafting. Taking first of all each figure and regarding the measurements as one determination made ten times, the results given below were obtained.

The total number of degrees in the ten measurements of the figure A was 18006, the arithmetic mean is therefore, 1800.6; the difference between this and the determination made by each individual is the error, now square each of the errors, the sum of the squares or $\Sigma v^2 = 24897$, as $n = 10$ we have

$$\begin{aligned} \text{Probable error} &= \pm .6745\sqrt{\frac{24897}{10 \times 9}} \\ &= \pm 11.1 \end{aligned}$$

If this is multiplied by $\sqrt{10}$ it gives the p.e. of each observer or $\pm$ 35 degrees. With figure B, the total degrees for the ten measurements was 12618, the mean is accordingly 1261.8; working in the same way $\Sigma v_2 = 16713$, the probable error

was, therefore, 9.1 and, as explained above, the error for each was ± 29 degrees. Now we know from Euclid that the sum of the interior angles of any closed figure bounded by straight lines is equal to twice as many right angles as the figure has sides less four right angles; figure A has 12 sides, therefore, the interior angles are equal to 20 right angles or 1800 degrees. Figure B similarly has 1260 degrees. The actual and probable errors for each are given below.

Observer	Figure A Actual error		Probable error for each	Figure B Actual error		Probable error for each.
1	—	10	.....	+	100	
2	+	65	.....	—	5	
3	—	68	.....	—	2	
4	—	69	.....	+	27	
5	—	37	.....	+	36	
6	+	47	..... ± 35	—	18	± 29
7	+	33	.....	—	13	
8	+	75	.....	—	50	
9	—	30	.....	—	22	
10	±	0	.....	—	35	
	+	6		+	18	

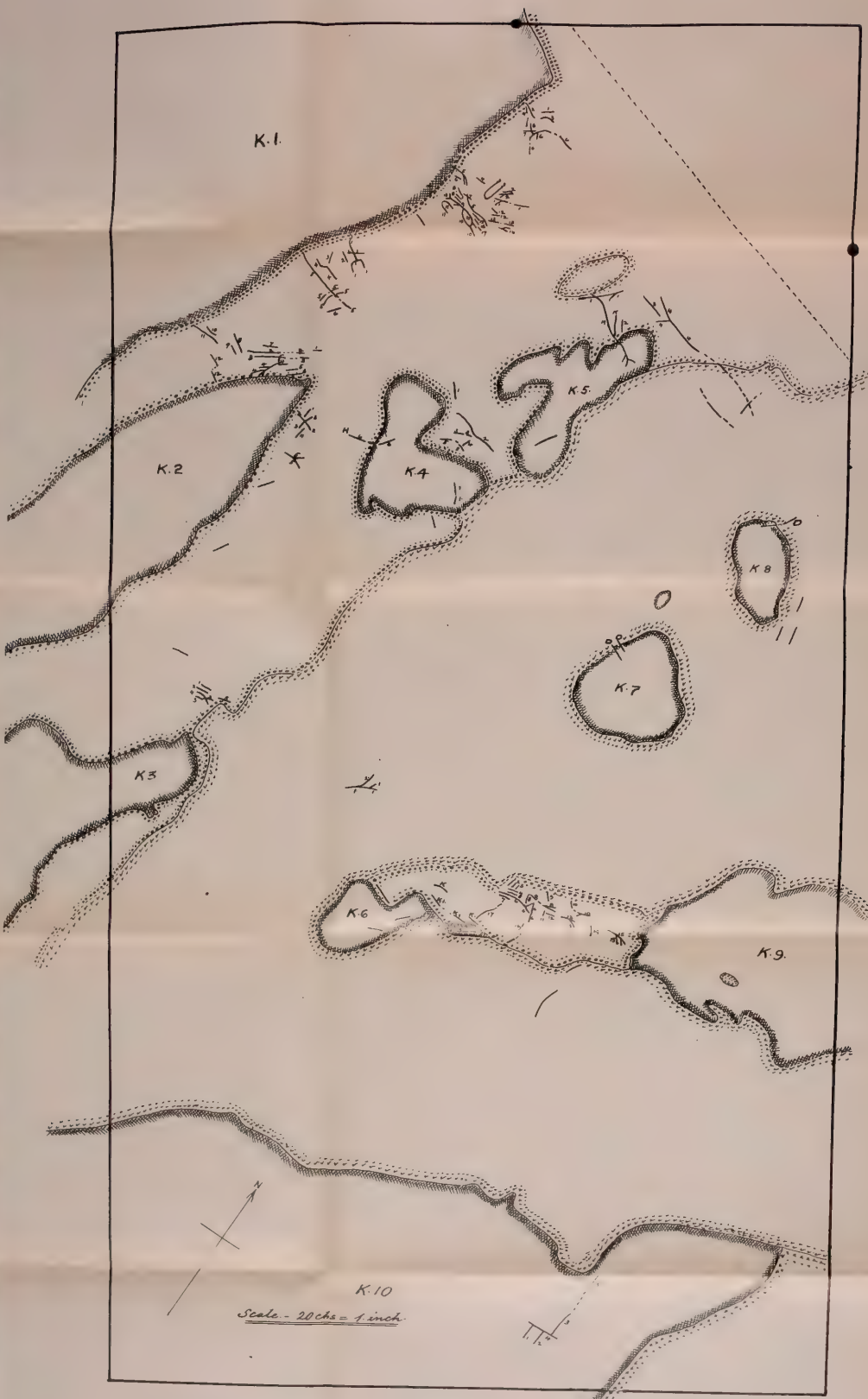
If we add the errors without sign we have 434, the arithmetic mean of the errors for figure A is, therefore, 43.4. For B, similarly, it is 30.8. It is clear then that even with these rough inaccurate measurements not only is the truth closely approximated, but the formula also indicates the magnitude of the error, in the one case the probable error being 11 degrees and the actual 6 in a total of 1800 degrees, and in the other 9 and 18 respectively for probable and actual error, the total being 1260 degrees. The arithmetic mean of the actual errors is also close to the probable error.

To further test the formula all the angles in both figures were measured by a protractor and the difference between the eye measurement and the protractor measurement was called the error, then we have in all 42 measurements made by each individual aggregating 3060 degrees. The formula was applied in each case with the results shown below, the different observers

being arranged in order of apparent merit judged by the actual error. The size of the probable error is, however, the true criterion of the accuracy of the estimates of any observer, as it proves whether he has persistently made small errors. The true order of merit is shown by the numbers in brackets.

	Actual error		Probable error		
Observer	Degrees	%	Degrees ±	% ±	
1.....	— 1	— .02	35	1.2	(6)
2.....	+ 20	+ .66	31	1.0	(3)
3.....	+ 25	+ .83	32	1.1	(4)
4.....	+ 29	+ 1.0	41	1.3	(8)
5.....	— 35	— 1.2	33	1.1	(4)
6.....	— 42	— 1.4	36	1.2	(6)
7.....	— 52	— 1.7	25	0.85	(2)
8.....	+ 60	+ 2.0	23	0.80	(1)
9.....	— 70	— 2.3	39	1.3	(8)
10.....	+ 90	+ 3.0	47	1.6	(10)

Here again it is shown that no matter how inaccurate the estimates are the result is a close approximation of the truth and the probable error never differs much from the actual error and is just as often greater as less, as indeed it must be from the definition.



Sketch showing productive Veins in Cobalt District
Geology - According to map by H.G. Miller & C.W. Wright, published in 1907 by Bureau of Mines

Legend

Diabase - Area	= 3.86 Sq mls
Huronian .	= 2.31 .
Granite .	= 0.18
Keewatin .	= 2.97
Total	9.32 Sq miles

G.L. Mackie

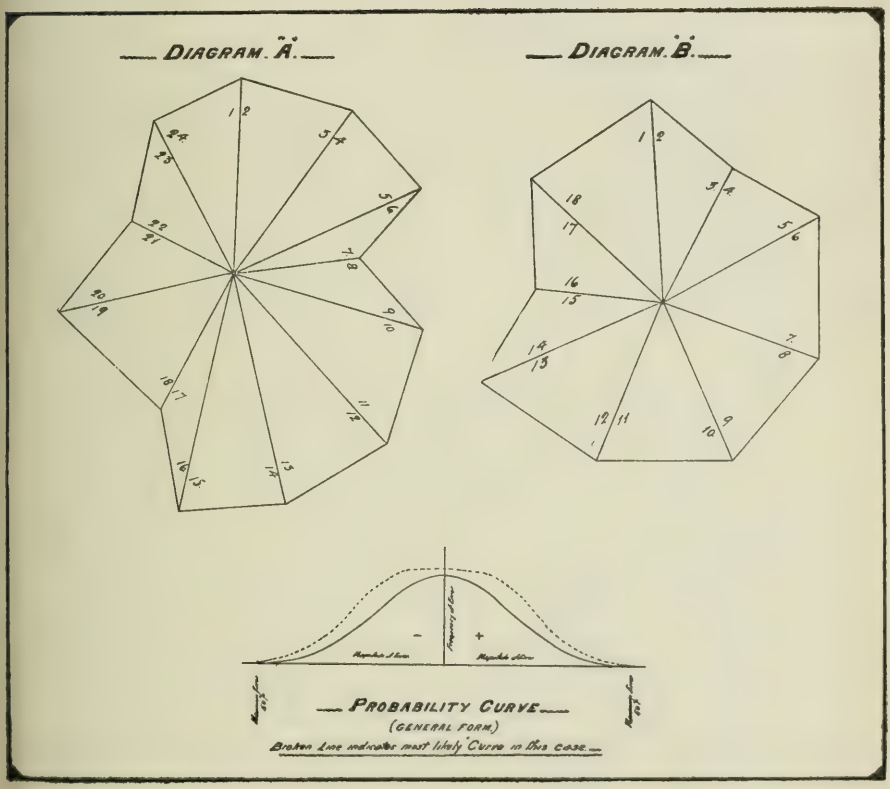


DIAGRAM. A.
DIAGRAM. B.
PROBABILITY CURVE
(GENERAL FORM)
Broken Line indicates most likely Curve in this case.

THE FUTURE OF THE COBALT DISTRICT, ONT.

By Charles A. O'Connell, Cobalt, Ont.

(*Annual Meeting, Toronto,* 1912.)

Having resided in Cobalt for the past seven years, I am more of an optimist than the majority of engineers, but the longer I live there the more I am convinced that this district is without a peer on the continent. The proved ore-bearing zone is a rectangle five by three miles, and from within this zone there has been produced in seven years to January 1, 1912, 126,064,189 oz. of silver. I do not think there has ever been anywhere on the continent a district as rich as Cobalt, which was so long producing before it attracted particular notice.

It was not until August, 1906, three years after the discovery, that more than passing notice was given the district. At that time there were about twelve producing properties. The whole of the township of Coleman had been staked, and any man who could show "Cobalt bloom" on his claim could sell it.

The production to date is stated as being 126,064,189 oz. fine silver worth $64,918,752. The first shipments were made in 1904. The total production in that year was 159 tons. In the following year the shipments amounted to over 2,300 tons, and thenceforward increased rapidly until the year 1910, when 33,000 tons was shipped, valued at $15,500,000. In 1911 the tonnage declined somewhat less than 25,000 tons being shipped; but the grade of the ore was higher, in consequence of the fact that a greater proportion was shipped in the form of bullion and concentrate.

It is difficult to state the exact amount of dividends paid, but the records show that $31,671,622 was distributed by companies making returns to the Department of Mines. To this should be added at least $2,000,000, representing the profits

from privately owned properties. From the inception of operation in the year 1904 to date, 47 separate mines have shipped to the smelters, but seventeen of this number did not contribute to the output during 1911. Much has been said and written as to the geology of the Cobalt area, and the articles by Miller, Knight, and others have been especially important. The bulk of the ore, as formerly, comes from the Lower Huronian formation, and while the amount contributed from the Keewatin series has been considerable, it forms only a portion of the whole. The quantity of ore extracted from the veins in the diabase is small. Since the year 1906 the extent of the proved ore-bearing zone has not been enlarged. The limit is marked on the south and the east by the Temiskaming mine, on the west by the Princess, and on the north by the Hudson Bay. The district west of the town of Cobalt extending to Portage Bay has been prospected, but no productive veins have yet been found. The properties on what is termed the "West Ridge" extending from the Hudson Bay on the north to the Buffalo on the south, have been especially consistent producers. This is largely accounted for by the multiplicity of veins in the Huronian formation along the Ridge.

Taking a line from the Hudson Bay through the Trethewey, Coniagas, and Buffalo mines, there are, I would venture to say, in this area, more than eighty known productive veins. These largely belong to the main vein system traversing east and west, from which innumerable branches lead. The Trethewey property alone, from the main vein system near the south end of the property, has twenty-two productive veins. Some of these are branches from the main vein system, which strikes east. It will doubtless interest all mining engineers and geologists to know that only four of these veins showed a marked outcrop on the surface. More than six do not come closer to the surface than 50 feet.

As to the origin of the ore, much has been said and written during the past eight years, and many theories have been advanced. Personally I am firmly convinced that the theory first advanced by Miller is the only one tenable.

During the past three years much has appeared in the public press as to the decline of the Cobalt district, but I am extremely doubtful whether the peak of production has yet been reached. The immense quantity of milling ore which is to be extracted leads to the belief that the maximum number of tons per annum will not be reached for several years. The Nipissing Mines Co. is now constructing a mill with a capacity of 200 tons per day, and this will be in operation some time in the autumn. This addition will largely increase the output of the district, as the Nipissing continues to be the premier producer. On this property, comprising 846 acres, have been found the greatest number of veins, and the tonnage of milling ore will undoubtedly be much larger than that contained in any of the other mines in Cobalt. There has been a vast improvement in the method of concentration during the past five years, and the tonnage in all mills has been largely increased.

The history of most mining districts of a similar nature shows that the time from the inception of operation to that when production attains its maximum rarely represents more than seven or eight years.

The decline to nominal production covers a much larger period and when it is known that there are extremely favourable chances of finding other productive ore-bodies within the proved ore zone, it will be seen that ten years would not be too long a period to estimate as the future minimum life of Cobalt. I am willing to predict that the total production will exceed 250,000,000 oz., and while this statement may be criticized as being the extreme view of an optimist, I make it without reserve, for it is largely based on the figures covering the past seven years' production as herein given.

Discussion.

Mr. W. E. H. Carter:—I would like to ask Mr. O'Connell whether he thinks (in view of the large proportion of unprofitable mining operations in the diabase formation in the Montreal River district) that the actual mining work expended on

veins in the diabase in the Cobalt district, leaves a net profit on the gross production mentioned of 5,000,000 ounces.

MR. O'CONNELL:—My paper and my observations are in relation to the Cobalt District exclusively. I do not care to answer this question off-hand. I cannot, however, see any connection between the deposits at Elk Lake and the Montreal River sections with those of Cobalt.

MR. CARTER:—You have misunderstood me. I had no intention of asking you to make a comparison between the Cobalt and the Montreal River districts, for as you will observe my mention of the Montreal River district was in the nature of a preface to my question to show the reason for asking it. I ask again, therefore, if you believe from your experience in the Cobalt camp that the actual amount of money expended in extracting ore from the diabase formation in the Cobalt district shows a net profit on the ore that has been won.

MR. O'CONNELL:—Undoubtedly, the Kerr Lake mine No. 3 vein has paid large profits. The Colonial and the Silver Cliff are in the diabase and both are productive. The King Edward (a vein in diabase), was productive. Speaking generally, ore found in diabase in the Cobalt camp has been profitable.

MR. W. E. H. CARTER (communication to the Secretary):—I did not carry this discussion further because Mr. O'Connell tended to treat it in an off-hand manner. I may say, however, that I did not and do not consider his answer satisfactory, for unless one takes into account the capital investment one cannot properly figure net profits. From my own limited knowledge from personal observation, I greatly doubt whether the King Edward mine, or the Silver Cliff, or the Colonial have anywhere nearly returned their capital investment and expenditures to date. I do know a number of other mines in the Cobalt district on which large sums were spent in an endeavour to find ore in the diabase formation, and the results were most disheartening and unprofitable. Hence, my original question. The veins in the Montreal River district are in the vast majority of cases all in the diabase formation and many operators are still spending money on development in the hope that they will ultimately strike pay ore bodies. If it could be said that

the diabase formation at Cobalt, by itself, was productive of pay ore bodies then it is not too great a stretch of the imagination to infer that there is a possibility of obtaining the same result in the physically similar veins in the diabase in the Montreal River district.

MR. J. B. TYRRELL:—Mr. O'Connell's paper is deserving of serious consideration. He has had opportunities of watching the camp almost from the time of its beginning up to the present, and his estimates of its probable future production are thoughtfully made, and, in my opinion, are very conservative. Everyone who knows anything about the geology of the Cobalt District knows that the Post-Huronian diabase occurs in that immediate vicinity in the form of a flat lying sill, and it is also now very generally recognized that the silver-bearing veins have been formed in fissures caused by the cooling of this diabase, and that these fissures extend upwards and downwards from the sill, and in some cases into the sill itself.

Now in the very middle of the silver-bearing area there are hundreds of acres which are immediately underlain by the diabase sill and in which no productive veins have yet been discovered, but whether there are rich veins beneath the diabase or not we do not know. We do know that in the country to the south where the diabase has been removed by erosion there are enormously rich veins and we also know that in the region to the north and west where the diabase has also been removed there are similarly rich veins, but of the country between we know little or nothing. I should not be at all surprised if in years to come, after the prospecting in the Cobalt camp is completed, the rocks beneath the diabase would produce as much, area for area, as those properties which have yielded so much silver in the past.

THE AMHERST (QUEBEC) GRAPHITE DEPOSITS.

By Fritz Cirkel, Montreal, Que.

(*Annual Meeting, Toronto,* 1912.)

Graphite, especially the flake variety, commands now a higher price than at any time in its history, and the present increased activity in developing Canadian graphite deposits may be ascribed to that cause. Extended operations are reported from the Buckingham district, where recently two new graphite mills have been erected. Another large mill is in course of construction near Wilberforce, Ont. The recent discovery of additional deposits in the Laurentian district, along the line of the Trondal, Bancroft & Ottawa R.R., Ont., seems to indicate that Canada will yet participate, perhaps to a considerable degree, in the world's production of graphite.

It has often been said that the graphite industry will remain a minor factor compared with the other mining industries of the Dominion, owing, so it is asserted, solely to the limited character of the deposits. This is clearly a misconception of the existing conditions and facts. The principal difficulty encountered pertains to the concentration of the graphite, as a result of the similarity of the specific gravity of associated minerals. For example, a Canadian company owning valuable ground with proven ore bodies has spent $120,000 in experiments covering a period of four years; in addition, this company paid $80,000 for the erection of a modern milling plant. Another mill with a capacity of two tons of refined graphite per day cost the owners, on account of the numerous alterations and additions to the machinery, $105,000, whereas this same plant can be replaced now at a cost of $35,000. Other instances can be cited; but the two above-mentioned may suffice to illustrate the difficult task of concentrating graphite ores which occur under different conditions within the same locality. But as a result of experimentation in Canada and the United States, and also in Europe,

certain processes have now been evolved which, if properly applied, render the success of a graphite mining enterprise now-a-days less problematical than in former years.

The Canadian graphite deposits are generally classed in three groups, namely:

(1) Veinlike occurrences.
(2) Bedlike occurrences.
(3) Dissemination through the country rock.

In the first group the graphite constitutes the filling of fissures in gneiss, crystalline, limestone, pegmatite and granular eruptive rocks. These deposits have been mined in several localities in Canada; but in almost all cases their exploitation, because of the narrowness and irregularity of the veins, has not proved remunerative.

The principal features of bedded veins or masses is that their general outlines and main direction conform with the stratification of the country rock; they form in the majority of cases disconnected layers, lenticular masses, or chain-like accumulations between the layers of the enclosing formation, giving off sometimes branches or apophyses, which, again, are accompanied by parallel lenticular masses or by widespread dissemination of graphite through the country rock. Deposits of this class are now profitably mined in Calabogie, Que., also in Bavaria and in the Bohemian Forest.

The third class, namely, disseminations through the country rock, is characterised by the occurrence of graphite in the form of fine films, scales or plates scattered through certain portions of the country rock. This mode of occurrence is less desirable from a mining point of view than the other two, since it involves the handling of a large tonnage of rock. Many mines, however, in North America owe their existence to deposits of this character; experience has shown that the size of the deposits of this type renders their commercial extraction lasting and profitable. To this class belong all the successful mines of the Buckingham district.

The Amherst graphite deposits were presumably discovered about ten years ago, exploratory and mining operations of a spasmodic nature being carried on between 1904 and 1907, when

some of the properties were acquired by a Montreal company. These properties are situated twelve miles from St. Jovite station on the C.P.R., or thirteen miles from Huberdeau, on the C.N.R., at a distance of about eighty miles from Montreal.

Physiographically the region is one of undulating hills not exceeding an altitude of 300 ft., and which are composed of flesh-coloured gneiss or granite. The country is dotted with little lakes connected by small creeks draining towards the south by the Maskinonge river into the Rouge river, a tributary of the Ottawa.

Scant attention was at first paid to the accidental discovery of rock fragments containing flake graphite, and only when several outcrops and large boulders were found at different localities in the neighbourhood, was search for the main deposit made, the existence of which was soon established on lots 15 and 16, range VI, of the township of Amherst. Continued prospecting established the presence of a graphite-bearing zone, extending from lot 13, range VI, to lot 20, range VII, a distance of about two miles.

The principal rocks met with in this district are practically confined to the crystalline gneisses and limestones of the Grenville series. These crystalline limestones, gneisses and quartzites are intruded by numerous masses of eruptive rocks such as pyroxenite, granite, and less frequently by diorite and diabase. The general trend of the series is north-east. Locally the series is contorted, dislocated and interrupted by faults which may be followed in some instances over long distances. The graphite deposits occur within eruptive rocks, striking between N.E. 62 and N.E. 70 degrees, with a dip of between 50 and 65 degrees to the east. Exploration work appears to indicate that the deposits, as yet developed on the surface, occur within a range of from 150 to 250 feet covering a distance of over two miles. Lenticular masses and pockets of graphite varying in size from a few inches to several feet in diameter, small veins, disseminations, branches, apophyses, nests, kidneys and irregular aggregations of the mineral together with the gangue, constitute alternatively these bandlike portions of the ore zone. Work also demonstrated that the larger bodies occurred within certain limits and along definite zones, which suggested that mining

should be carried on by shafts and drifts. The present development work consists of a shaft 100 feet deep. At 40 feet one of the bandlike deposits which appeared on the surface was encountered, and drifting thereon is now in progress. Another of these bedded masses or veins, whose outcrops are located close to the shaft, was encountered by the latter at a depth of 90 feet, and the cross-cuts to the north and south should determine the actual widths of these bodies in their respective depths. On the surface the graphite deposits have a strike of N. 62° E. They are developed by small shafts, crosscuts and other openings and a large quantity of ore is exposed. The graphitic portions of the ore zone on the surface are between 10 and 12 feet wide, in some places wider, the main portion consisting of graphite scales and flakes or radiated individuals. The larger flakes, some of them one or two inches square, when freshly found are prevailingly curved as though from pressure. They break in the direction of the platy structure into more or less angular aggregates, being composed of thin narrow foliæ of uniform width. Blocks of this almost pure graphite have been taken out measuring 1½ to 2 cubic feet. This class of ore is designated as "crude" or "cobbing" ore, and contains, according to the quantity of rock matter mixed with it, from 65 per cent. of fixed carbon and upwards. The very pure aggregates of crystals have a fixed carbon content varying between 92 and 98 per cent. A portion of this crude material was crushed to flakes, and the latter analysed. The purity of these flakes was found to be 95.60 per cent. (Prof. Chas. H. White, of Harvard, Cambridge, Mass.).

The other class of ore taken from the deposits is designated as the disseminated variety, or milling ore. It is composed of streak and lense-like accumulations of flakes of the smaller size, the gangue consisting, in the main part, of feldspathic, pyroxenic rock-matter and wollastonite.

The ore of the Amherst deposits is remarkably free of these objectionable admixtures which usually impede the successful extraction of the graphite from the gangue, or render even the refined article unfit for the manufacture of most of the graphite products. There is no iron, mica or pyrite (with its most ob-

Outcrops at graphite ore mine. The width of the deposit is here 15 feet.

Derrick and surface equipment at the Amherst Graphite Mine.

jectionable sulphur) present; while lime remains (in almost all the average tests so far made) below the permissible minimum, that is, below 5 per cent. Most of the graphite is associated with feldspar or pyroxene, less frequently with wollastonite or calcite.

A selected sample containing much calcite gave, upon analysis by Prof. Chas. White, of Harvard, Cambridge, Mass., the following composition:

Moisture	0.13
Carbonic Acid	4.26
Other volatile matter	1.12
Free Carbon	54.75
Ash	39.74
	100.00

The mineral composition resulting then as follows:

Graphite (carbon)	54.75
Feldspar	34.32
Lime	5.42
Carbonic Acid Gas	4.26
Volatile matter	1.12
Moisture	0.13
	100.00

During the development of this deposit the writer has endeavoured, as far as circumstances permitted, to solve two most important questions; first, what is the percentage of crude and milling ore in the total rock mined and, second, what is the average percentage of graphite contained in the mill rock? As to the first question, it was found that, based on operations covering a period of several months, a total of 750 tons of material gave the following figures:

Overburden (stripping)	110 tons
Rock	398 "
Disseminated or mill ore	227 "
Crude (almost pure ore)	15 "
	750 "

Eliminating the 110 tons of overburden, we have a total of rock and graphite ore of 640 tons, which is divided up as follows:

Rock	398 tons	62.0%
Disseminated or mill ore	227 "	35.7%
Crude ore	15 "	2.3%
	640 "	100.0%

or, in other words, one hundred tons of rock mined gave 62 tons of waste, 35.7 tons of mill rock, and 2.3 tons of crude ore or almost pure ore.

From certain preliminary tests the writer believes that the mill rock contains between 12 and 18 per cent. of graphite.

Some attention has been paid to the concentrating and refining of the ore, and experiments demonstrate that a combined dry and wet method will yield satisfactory results. A parcel of 1220 lbs. was subjected by the Krupps works, in Essen, to a combined dry and wet process test and the following results were obtained:

After the first grinding in a special mill, the following extraction was made:

	Kilos.	P. C. carbon
Coarse	132.25	95.4
Middle	244.00	93.4
Fine	20.30	93.9
And after the grinding of the millings:		
Coarse	88.80	94.1
Middle	167.20	93.00
Fine	56.00	87.00
	708.55	93.3

The crude material before treatment contained 66 per cent. carbon, hence the amount of carbon in the milling process was raised to 93.3 per cent., an increase of 41 per cent. One would need, therefore, 1.7 tons of crude graphite in order to produce one ton of the finished article.

Other tests with the ore showed that the gangue materials are easily reduced to fine powder, which settles in water more

slowly than the coarse graphite. A quantity of the material finely crushed and allowed to settle under water was found to contain more and more graphite as depth was attained.

From all the experiments it appears that the high grade flake graphite can be separated in a dry state in a coarse condition, while the residue may be treated in water. Experiments have also shown that this graphite may possibly be separated from the gangue "electrostatically," and it is not unlikely that such a process may be worked out before long. The writer submitted a parcel of 100 lbs. for a preliminary test to the Huff Electrostatic Separator Company, of Boston, Mass., and the tailing from this test were without question quite clean. The middling consisted of graphite with attached gangue particles, and need regrinding before they can be again submitted to the electrostatic treatment. In the concentrate there appears to be free rock, but there was some attached gangue in both sizes of concentrate. The writer believes that if this product were submitted to the polishing treatment, it is likely that a clean article may be the result.

The rock minerals making up the gangue of the graphite lode may be grouped into two classes, namely, one comprising the chief minerals, which constitute almost the entire gangue, and the other one comprising those minerals which play a secondary part or as a component may be regarded as entirely negligible. The principal constituent is the feldspar. With the graphite it occupies over three-quarters of the entire deposit. Almost all the varieties are present as orthoclase (sometimes perthite), microline, plagioclase, albite and anorthite. They all have a white glassy appearance and are frequently graphically interlocked with quartz grains. Under the microscope most of the feldspars contain fine needles of apatite, fine crystals of titanite and garnet, more rarely scapolite and muskovite. Pyroxene is freely distributed through the feldspathic matrix as augite and hypersthene of a dark green colour. Quartz is also frequently associated with the pyroxenes in the form of small grains. Wollastonite (silicate of lime) is a frequent companion of the feldspar, and graphite scales and crystalline accumulations of graphite in wollastonite crystals are very frequent. It occurs

mostly in large tubular crystals of a very pale green to white colour. It is a highly brittle mineral, its lustre is vitreous, and on cleavage its surface is pearly. Thin sections of this mineral under the microscope almost invariably along the cleavage planes show enclosures of augite, calcite and minute crystals of titanite. The very brittle nature of this mineral facilitates its separation from graphite in a dry state. Calcite occurs in large crystals of rhombohedral form, the colour being a pale green. It is irregularly but sparingly distributed through the gangue, its constant companion being either wollastonite or graphite. The latter in scales of ¼ to 1 inch square, is often embedded in the larger crystals of calcite individuals, and in this condition furnishes excellent mineralogical specimens

Of the second group of minerals, or those which play a negligible part in the constitution of the gangue and occur only as scattered grains, small crystals or minute scales through the pyroxene and feldspar, may be mentioned: scapolite, garnet, titanite, zircon, muscovite, pyrite, apatite, leucoxene, biotite, monazite and magnetite. The most remarkable of these minerals are the garnet and zircon. They occur sometimes in small but brilliant crystal accumulations, mostly in association with calcite, quartzose feldspathic rock and pyroxene, and exhibit beautiful iridescence, that is, the property of the mineral to display colours in rapid succession when turned.

The origin of the graphite deposits is a question of scientific rather than economic interest; but a few facts have been brought out during the course of the development work, and also by microscopical examination of thin rock sections, which might have a bearing on the distribution of the mineral through the rock matrix. In his treatise on "Graphite, its Occurrence, Refining and Uses," the writer has laid down the views of many authorities which were held at that time (1905) regarding this important subject, and in his opinion there is not one mineral whose origin has been the subject of such controversy or of so many hairsplitting theories as those pertaining to graphite. The most important of those theories, and the one which has caused much discussion amongst European geologists, is the one advanced by Weinschenk. According to this authority, the source

of the carbon in the case of eruptive rocks must be sought deep down in the earth. Weinschenk ascribes the formation of graphite in these deposits to the probable action of volcanic gases, probably of carbon compounds of the cyanogen group and of iron in the presence of carbon dioxide and water, all of which, having ascended along lines of fracture in the eruptive rocks, deposited graphitic carbon through chemical agencies, that is, after the crystallization of the rock minerals out of the intrusive magma. In the case of the Amherst deposits there seems to be no doubt that the graphite is solely confined to intrusions of the eruptive rocks from below; but so far there is no evidence that the carbon of the graphite was the result of volcanic gases acting along fracture lines. The writer has submitted thin rock sections of the graphitic gangue to examination under the microscope, and it can be clearly seen that the graphite is embedded in fresh feldspar, in quartz and pyroxene, sometimes in well-defined crystals of these minerals. This naturally points to the presence of the graphitic carbon when the formation of these rocks took place; it shows further that the graphitic carbon was introduced before and not after the formation or crystallization of these minerals. This carbon was then very likely graphitized later on through pressure, heat and other agencies which played, at one time, an important part in the formation of the rocks and of which we know so very little.

SERPENTINE ASBESTOS DEPOSTS IN THE BEREZOWA, KAMENSKAJA, AND MANETNAJA ESTATES, URAL, RUSSIA.

By W. F. Kryshanofsky.

Published by the Geological Museum of Peter the Great, Imperial Academy of Science, St. Petersburg, 1904.

Translated by A. Anrep, Ottawa.

(Abstract.)

The Ural asbestos deposits are situated about 30 versts (1 English mile=1.0668 Russian versts) from Bagenowa station, Perm Tjunenskay Railway, or about 85 versts northwest from Ekaterinburg. Except for a few outlying deposits, the asbestos is in the timber limits of the Berezowa, Kamenskaja and Manitodaja estates. The deposits in Berezowa estate are owned by Baron Shjerada and those in the Kamenskaja and Manetnaja estates by the Ural (Italian-German) Corporation.

The surface of the country is flat and poorly drained and shallow lakes and bogs are numerous. There is a heavy growth of spruce timber and the nearest villages are 25 to 30 versts from the asbestos deposits. Consequently prospecting and development are difficult.

Serpentine and allied rocks form a belt 2 to 3 miles wide, extending 30 miles north and south and preserving the north and south direction with striking regularity. It lies wholly within granite which occupies a large area in this region.

The rocks of the belt are chloritic and talc schists, diabase, porphyrite and serpentine. The schists in places carry emeralds and other gems. The serpentine is in elliptical areas, which appear at intervals and have their longer axes running north and south: that is parallel to the length of the belt. One of the largest bodies of serpentine is about 1,000 feet wide and a mile long.

Some narrow portions of the belt consist only of diabase and porphyrite. In places serpentine contains veins (dikes?) of porphyrite.

The asbestos is in veins which form a sort of stockwork running in all directions through the rock. They disappear, recur and spread out in all directions from 0° to 360° and from horizontal to vertical, both horizontal and vertical veins being quite numerous. The veins fork, or unite, and form "all imaginable kinds of triangles." Veins are frequently crushed showing movement of the rock since the veins were formed.

In places, the veins are as much as 20 centimeters (8 inches) wide. The fibres run across the veins at right angles to the walls and vary in colour from pure white, yellow, golden, rarely red, to bluish and darker shades. The colour does not appear to indicate any difference in other qualities. The central part of the veins contains streaks of serpentine rock rich in magnetic iron ore. The fibres are closely bound together; but the "cohesiveness" is not equal to that of the Canadian asbestos. Near the surface the rock is loose and disintegrated.

There is also a kind of asbestos (picrolite?) with fibres a yard in length. These fibres run parallel to the walls and are coarse and unsuitable for use.

Other minerals.—Magnetite occurs well crystallized in veins and small aggregates. Crystalline quartz, chalcedony and rarely milky opal are found and also garnet, vesuvianite and chlorite. The species of garnets noted are grossularite, ouvarovite and andradite.

Besides the above a lime-iron-magnesium carbonate and arragonite are occasionally found.

History.—Asbestos was found in the Ural district by a farmer named Sofron Sogra between 1710 and 1720, and mining was undertaken soon after by Nikita Demidof, one of the founders of a well known family in the district. A process of manufacture known as the Nevjansko process was devised and textiles, socks, gloves, handbags, etc., were made for 50 or 60 years. The industry failed owing to limited local demand for the products, and lack of transportation. A few samples of the

work of pioneer manufacturers, now preserved in museums, are the only traces left of this early industry.

The present operations date from 1883 and have been vigorously prosecuted since 1889. The mines are principally in the hands of large capitalists and are efficiently equipped. Steam and electric power are used and the works are equipped with electric light, telephones, etc.

Mining.—Mining is carried on in open pits, the ground being cut down in benches of about seven feet so as to admit of tramways through the pits. The rock especially near the surface is so weathered that explosives are little used, except to break up harder remnants of the rock. Horses are employed for moving the rock in the pits. The mining is largely done by contract.

Treatment.—The harder rock is treated in mills where it is crushed by stamps or rolls, dried and screened and the products classified by a kind of rotary classifying screen. Fibre from the softer rock is washed dried and screened. Five grades of asbestos are distinguished according to the length of fibre from ½ centimeter to 4 centimeters or longer. These mechanical processes for the separation of asbestos were in use in Russia before mechanical concentration was employed in America.

Peculiar Working Conditions.—Owing to the severe winters, work is carried on only during the summer months and even then only in the intervals between farming operations. Work is usually begun in May and continued through June. For the following two months the mines are idle because most of the labourers are farmers and during that time are attending to their farms. The mines are again worked during September and October. Over 15,000 labourers were thus employed in a year for a production of 6,000 tons.

Excellent accommodation is provided for the labourers at the mines, where they have good food and lodging, free medical care, and even schools.

CO-OPERATIVE MINING INVESTIGATIONS IN ILLINOIS.

By H. H. Stoek, University of Urbana, Urbana, Ill.

History.—During the early part of the year 1899 a mine rescue station was established at the University of Illinois in Urbana under the joint auspices of the State Geological Survey, the Technologic Branch of the U. S. Geological Survey, now the United States Bureau of Mines, and the College of Engineering of the University of Illinois. The purpose of this station was to demonstrate to the mine inspectors, mine operators and miners of the middle west the economic value of oxygen helmets and resuscitation appliances as a part of the normal equipment of a modern mine. At the station, mine bosses and others, during the past three years, have been trained in the use of such apparatus, the training being directed gratuitously by a resident mining engineer and foreman miner of the U. S. Bureau of Mines, supplemented by technical lectures given by these officials and by the members of the State Geological Survey and the Department of Mining Engineering of the University of Illinois.

In connection with the initial announcement of the station, as contained in the catalogue of the University of Illinois, there appeared the statement, "it is expected that about the present station as a nucleus other laboratories for experimental work in connection with mining will be developed."

The 47th General Assembly of the Illinois Legislature, held during 1910, included among its appropriations two specific items in support of a co-operative investigation of mining conditions in the State of Illinois. An appropriation of $4,500 per annum for two years was granted to the State Geological Survey and an appropriation of $5,000 per annum for two years to the Department of Mining Engineering at the University of Illinois

"for work of investigation in co-operation with the U. S. Bureau of Mines with a view of conserving the lives of the mine workers and the mineral resources of the State."

A formal agreement with the U. S. Bureau of Mines was arranged in August, 1911, outlining the general nature of the investigations to be undertaken and fixing the responsibilities of each of the parties to the agreement. As this is the first instance of such co-operation between the U. S. Bureau of Mines and State institutions, it was necessary to make a very careful preliminary study of the field to decide upon the best methods of carrying on the work and to determine which of the many problems should be investigated with a view to obtaining speedy results likely to be of value to the mining industry of the State; and to provide, moreover, that a broad foundation should be laid for subsequent and continuous scientific work. Conferences were held with the State Mine Inspectors, the several Mine Operators' Associations of the State, with the Illinois representatives of the United Mine Workers of America and with individual engineers and operators; in fact, an effort was made to enlist the support and secure the advice of all who might be interested in such an investigation.

As a basis for the work the mines of the State have been grouped into nine (9) districts, the grouping being as nearly as possible upon the basis of mines working in the same seam of coal. In Illinois at present five (5) seams of coal are being worked commercially and such a division of mines by the seams of coal worked can be fairly easily made, as there are only a few instances in the State where more than one seam is worked at the same mine, and as a general rule the mines in a given locality are usually working the same seam of coal. The districts, the seams worked, and the number of mines in each district, are as follows:—

District 1, No. 2 seam, Northern Illinois, 11 mines, long wall method.

District 2, No. 2 seam, Southern Illinois, 5 mines, room and pillar method.

District 3, Nos. 1 and 2 seams, in Western and Northwestern Illinois, 8 mines, room and pillar.

District 4, Nos. 1 and 5 seams, Central Illinois, 18 mines, room and pillar.

District 5, No. 5 seam, Southern Illinois, 7 mines, room and pillar.

District 6, No. 6 seam, Southeastern Illinois, 16 mines, room and pillar.

District 7, No. 6 seam, Southwestern Illinois, 25 mines, room and pillar.

District 8, Nos. 6 and 7 seams, in Eastern Illinois, 7 mines, room and pillar.

District 9, mines working two seams in Northern and Central Illinois, 4 mines.

The geographic boundaries of these districts are of local and not of general interest.

About one hundred mines have thus been chosen for detailed investigations, representing about one-fourth of the shipping mines in the State. As an especial effort has been made to choose representative mines in each district, the conclusions drawn from data secured in these mines should represent the general conditions throughout the State.

A series of data sheets have been prepared covering the following headings:—

A. Surface.
B. Underground.
C. Humidity.
D. Timbering.
E. Blasting.
F. Mine Fires.
G. Mine Squeeze.
H. Preparation.
I. Coal Sample.
L. Geological, Surface.
M-N. Geological, Underground.
X. Extra Sheets, Miscellaneous.

At present the field is being carried on by two parties, each of which consists of a mining engineer, a geologist, and a sampler, who also assists either the engineer or the geologist as required. It is planned to have a common field headquarters for the parties, at least during the initial stages of the work, so that conferences can be held at night by the several parties.

The first district chosen for investigation is the Danville Field, District 8, located only thirty miles from Urbana and easily accessible either by railway or interurban service, so that frequent conferences can also be held between the field parties

and those connected with the Geological Survey and the University who are directing the work for the State. It is probable that as soon as the field work in the Danville district is completed a report will be prepared before continuing the field work in another district. Subsequent developments may, of course, show that it is advisable to continue the field work in other districts before undertaking a report. The data for each district will be published and conclusions drawn therefrom in preliminary bulletins; and after these have been completed a summary of the data for the whole State will be published and general conclusions drawn therefrom.

It is impossible to state in advance just what problems will be given special study in each district, as this will be determined as the field work progresses. In the Danville field, where the work is now being carried on, there are two prominent geological features that affect the mining and that make systematic development difficult, namely: a very poor roof and a series of faults or horsebacks. A systematic study of these horsebacks is being made as one of the geological contributions to the work.

Hygrometric Survey of the State.—An important feature of the investigation, having a bearing upon the dust problem, is a detailed hygrometric survey of the State to determine the amount of water taken out of the mines in winter and put into them in summer by the ventilating currents. Twenty mines have been selected scattered throughout the State, and in each of these, two standard hygrometers have been placed, one in the down-cast and the other in the up-cast air current. At least three readings a day are taken of each of these hygrometers by the mine officials and the results recorded on postal cards and forwarded to Urbana, where they are tabulated. With this information, with the knowledge of the volume of air circulating through the mine, it will be possible to determine the variation in the moisture content of the mine air. In order to determine the average moisture condition of the surface, daily readings are made with hygrographs and thermographs at the stations of the U. S. Weather Bureau. These stations have been selected so as to surround the coal area in which the hygrometers have been placed. The observations will be continued for at least one year,

possibly longer; and in addition to these daily readings at the up-cast and down-cast a systematic study will be made to determine the moisture condition of the air at various points along the air current. In this part of the work the U. S. Weather Bureau is co-operating.

Dust Experiments.—Another series of experiments are already under way; namely: an examination of coal dusts of the State to determine their explosibility. A laboratory has been fitted up by the Department of Mining Engineering of the University, in which appliances have been installed similar to those in use in the Bureau of Mines' laboratory in Pittsburgh. A chemist of the Bureau of Mines has been stationed in Urbana to carry on this work along the lines adopted for similar work at the Pittsburgh laboratories.

Study of Gas Evolved by Coal.—Mr. N. H. Darton, Geologist of the U. S. Bureau of Mines, is at present studying in Southern Illinois the relation of the evolution of mine gases to the geological structure of the coal field. This is a similar investigation to one upon which Mr. Darton has been engaged in the anthracite mines of Pennsylvania for several years past.

Examination of Explosives.—Another line of investigation that has been decided upon is a study of explosives and other methods of bringing down coal. These investigations will be under the direction of Dr. J. J. Rutledge, of the U. S. Bureau of Mines, and will be begun in the near future.

As this work is but recently started it is impossible and it would be unwise to prophesy results. It is believed, however, that the work outlined and in progress is the beginning of a scientific study of mining conditions in the State of Illinois that will be of great and permanent economic benefit to the mining industry of the State, and that, in general, scientific results of value will accrue.

NOTES ON THE GROUNDHOG COAL BASIN, SKEENA DISTRICT, B.C.

By G. S. Malloch, Ottawa, Ont.

(*Western Branch Meeting, Vancouver, Feb.*, 1912.)

Location and Area.—So far as known the coal measures extend in a northwesterly direction for at least seventy miles. The width of this strip at its southern end is about thirty miles, but it may not be so wide further north. The southern border extends from about latitude 56° 51′, longitude 128° 10′, to latitude 56° 44′, longitude 128° 52′.

Geological Section.—The coal measures have a thickness of upwards of 3,000 feet, but contain coal in commercial quantities near the top and bottom only, although there are a few thin seams in the intermediate beds. The lower horizon contains at least three seams of from four to six feet in thickness, and the upper seven seams, with thicknesses varying from two to six feet. The upper horizon, it is at present believed, is limited to an area of approximately twenty square miles; the lower horizon, however, extends over most of the above mentioned strip.

Structure.—The strike of the beds is prevailingly northwest and southeast. The dips to the southwest greatly predominate over those to the northeast. This is explained by numerous lines of thrust faults with downthrows to the northeast, so that the region furnishes an example of imbricate structure. Many local flexures occur in connection with the faults which have throws of much smaller dimensions than the gigantic thrusts so characteristic of the eastern ranges of the Canadian Rockies. The scarcity of exposures in the valleys and the presence of these disturbances make it difficult to trace the outcrops of the different seams.

Character of the Coal.—The coal is anthracitic in character, but some of the available analyses show very high percentages of ash. Many of the seams have been so crushed that the coal shows

numerous cleavage faces and powders badly when handled. In all the seams seen, veinlets of quartz or calcite traverse the coal in different directions. These veinlets are usually between a quarter and an eighth of an inch in thickness, and the foreign material almost invariably adheres to one or other of the pieces when the coal is broken. The places at which the coal has been opened are too few to permit of estimate respecting the amount of foreign material present, and it is quite possible that some localities may be found where the coal is entirely free therefrom. As a general rule, the veinlets are more numerous in the lower seams, where they average, perhaps, three to the cubic foot; while in two openings on one of the higher seams, one to the foot would be a more likely proportion.

The following are analyses taken in each case across seams which, after omitting the prominent streaks of bone and shale, represented a thickness of coal, as also expressed in the table:

No.	Seam	Sampler	Moisture	Vol. Comb.	Fix. Carbon	Ash.
1	5.5 ft.	Jas. McEvoy, from tunnel	1.17	6.05	76.20	16.58
2	5.5 ft.	G. S. Malloch, " "	1.04	8.39	67.89	22.68
3	5.8 ft.	Jas. McEvoy, tunnel	1.17	6.54	83.37	8.92
4	5.8 ft.	Jas. McEvoy, surface	2.39	7.90	78.54	10.18
5	1 ft. near top.	Chas Fergie, "	4.12	7.43	82.60	5.85
6	3 ft. at bottom	Chas. Fergie, "	5.95	8.00	84.00	4.05
7	5.4 ft.	Jas McEvoy, tunnel	2.62	6.96	84.49	5.93
8	5.4 ft.	W W Leach, surface	5.75	7.34	75.26	11.65
9	5.4 ft.	J. F. Walter, "	4.45	8.75	79.25	7.55
10	4.4 ft.	Jas. McEvoy, tunnel	1.40	6.06	70.68	21.86
11	4.4 t.	G. S. Malloch, "	1.57	7.55	65.52	25.36
12	5.2 ft.	G. S. Malloch, "	1.35	7.69	61.90	29.06
13	5.1 ft.	G. S. Malloch, "	1.08	7.06	64.97	26.89
14	6.6 ft.	Jas. McEvoy "	1.39	5.75	63.02	29.84

Analyses Nos. 1 to 9 represent the same seam outcropping at three different points.

The following are analyses of two picked samples, the first of which was taken from the 5.2 ft. seam, (No. 12) and the second from a seam in the eastern part of the basin, the thickness of which seam is reported to be 10 feet.

Moisture	Vol. Comb.	Fixed Carbon	Ash.
1.07	6.53	75.25	17.15
3.83	8.80	82.98	4.39

In no case is any tendency to coke apparent.

Transportation.—The marketing of coal from this field will necessitate the construction of many miles of railway. The nearest sea-port by direct route is at the town of Stewart, situated at the head of the Portland Canal. A line of railway has already been built for twelve miles from Stewart up the valley of Bear River, but some difficult rock work and two miles of tunnelling must be undertaken before the extension of the line to the broad valley of the Nass, about twenty-two miles distant from the present terminus. The grade on the western side would be about three, and on the eastern two per cent. These difficulties could be avoided by building a line up the Nass from the Nasoga Gulf, which is the nearest suitable harbour. The length of the line, should this route be selected, would be eighty miles greater than that required to complete the connection from Stewart to the same point on the Nass. In addition, some rock work would probably be encountered, although in compensation by following this route a very easy grade would be obtained.

To reach the Groundhog Basin from the Nass, several routes are available. Two of these, by way of Panorama and Anthony Creeks respectively, cross passes more than four thousand feet in elevation; both are direct, hence the distance from Stewart would be but little over ninety miles. Possibly a two per cent. grade might be obtained over these passes, but three per cent. would be a nearer estimate. An alternative route by the Blackwater lakes would cross from the Nass to the Skeena waters at an elevation of only 1,900 feet, and a one per cent. grade could be maintained; but the distance from Stewart would not be much less than 160 miles. Another possible route would be up the Skeena from Hazelton, a distance of 150 miles. This would entail much rock work, but a one per cent. grade would be possible. The distance from Hazelton to Prince Rupert by the Grand Trunk Pacific would represent a total railway haulage of more than three hundred miles.

DISCUSSION.

MR. A. E. HEPBURN.—It is to be hoped that in the Groundhog Basin some of the supposed anthracite will be found to contain at least 12 per cent. volatile combustible matter, as

"drier" coals and true anthracites, containing from 3 per cent. to 6 per cent., are not considered suitable for steam raising purposes in European countries, on account of their slow rate of combustion, although Pennsylvanian anthracite seems to be quite acceptable in some parts of the United States.

EARTHQUAKES, STRAINS AND STRESSES IN RELATION TO COLLIERY EXPLOSIONS.

By F. Napier Denison, F. R. Met. Soc., Victoria, B.C.

(*Western Branch Meeting, Vancouver, Feb.*, 1912.)

The present paper is supplementary to one on the same subject* contributed by the writer to the Institute in 1911. Since then he has had the opportunity of personally presenting some of these results in conjunction with other studies before the International Seismological Association which met at Manchester, England, last July.

These were favourably received and a summary of them is being published in the Association's *Comptes Rendus*.

Another paper on this subject was kindly read for me by Professor Milne at the September Meeting of the British Association for the Advancement of Science, held at Portsmouth. At the conclusion of which a resolution was passed favourably commenting on the work and asking that it be continued.

Since my return to Canada the Hon. the Minister of Marine has been pleased to allow a grant of $2.000 "for the purchase of special instruments for facilitating research in this direction in British Columbia."

The following notes record such additional information as has been obtained during the past year.

Respecting the apparent relationship between the times of earthquakes and colliery explosions, the dates of thirty-four of the latter which have occurred in Great Britain (including four European), from January, 1899, to December, 1911, have been

*Trans. C.M.I., Vol. xiv., p. 84.

studied in conjunction with the dates of all earthquakes recorded at Victoria.

The results are as follows:

26% occurred on the day of a quake,

29% occurred on the day after a quake, and

12% occurred on the day before.

That is 67% of the British colliery explosions occurred either on the day or within twenty-four hours of a day upon which a quake was recorded at Victoria.

One hundred and twenty-six colliery explosions which have occurred in North America have been treated in a similar manner from January, 1900, to December, 1911, with the following results:

22% occurred upon the day of a recorded quake,

16% occurred upon the day after, and 8% upon the day before a quake; that is, 46% occurred either on or within twenty-four hours of the day of a quake.

Although the above list of colliery explosions is doubtless incomplete and only includes those where five or more lives were lost, the above figures certainly point to some connection between earthquakes and colliery explosions.

As referred to last year, the writer has kept a constant record of the daily movements of the Victoria Seismograph, or Horizontal Pendulum, from 1899 to the present time.

These have been reduced to mean monthly values, and a curve for the latter clearly demonstrated the presence of a decided easterly swing reaching its maximum in midsummer and a westerly movement with a maximum at midwinter.

When these 160 explosions (under discussion) are grouped according to the months upon which they occurred, we find that when they are studied in conjunction with the monthly pendulum curve, that the explosions are chiefly to be found on or near to the months when the pendulum reaches its extreme easterly or westerly swing. As is well known the greatest num-

ber of explosions occur during the winter months. They reach their monthly maximum in December, which is also about the time of the extreme westerly swing of the pendulum. The grouping of explosions about the summer months, though not so pronounced, is decidedly noticeable.

In a former paper the writer directed attention to the remarkable secular movement of the Victoria Horizontal Pendulum, as shown in the monthly curve from January, 1899, to December, 1910. That is, taken annually there is a marked westerly swing to the winter of 1900, then a steady easterly swing to 1906, followed by a westerly movement to 1908, then an even greater easterly swing to 1910.

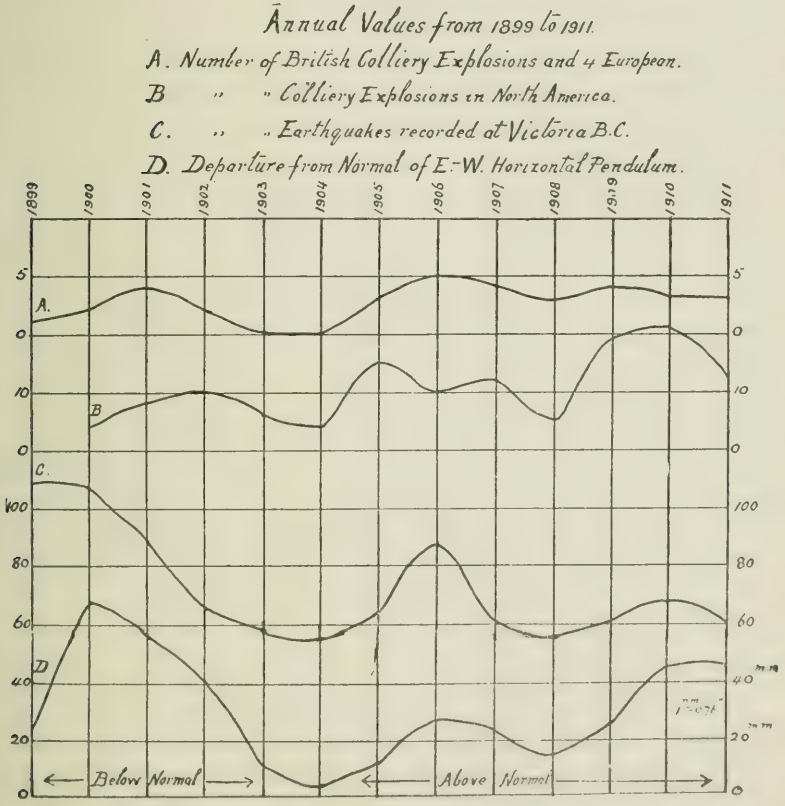
Under this curve was shown the annual number of colliery explosions for North America and the annual number of recorded quakes. Although these curves are certainly suggestive of some connection between them, the following table and diagram, derived from more data and another year's records, throw considerably more light upon this interesting subject.

TABLE I.

Year	Number of Quakes recorded at Victoria	Number of Colliery Explosions	
		In North America	In Great Britain (including 4 European).
1899	109	—	1
1900	107	4	2
1901	89	8	4
1902	66	10	2
1903	58	6	0
1904	56	4	0
1905	64	15	3
1906	87	10	5
1907	60	12	4
1908	61	5	3
1909	56	19	4
1910	67	21	3
1911	60	12	3
Total	940	126	34

Curve D. is obtained from the mean annual value of the Victoria Horizontal Pendulum, this mean is termed its "Normal" or "Zero." That portion of the curve called "below normal" represents a westerly movement, and the years above normal signify easterly deflections.

The other curves are self-explanatory. The chief points to note are:



The remarkable paralleling of the greater portion of these curves.

That the years when the pendulum is farthest from "Normal" are also years of greatest number of quakes.

That the years when the pendulum is nearest to "Normal," the fewest number of quakes are recorded. Carrying this comparison to the colliery explosion, curves A. and B., we find in A. a maximum in 1901, a minimum in 1903 and 1904, another maximum in 1906, minimum in 1908, and maximum in 1909.

The early portion of curve B., possibly due to incomplete data, does not show an agreement, but the remainder of the side of 1906, a minimum in 1908, followed by a remarkable rise in 1909 and 1910, and a fall in 1911.

From the appearance of these curves the writer ventures to suggest the presence of a five to six-year cycle, not only noticeable in the pendulum movements, but the quake and colliery explosion curves also.

If this should prove correct we may look for another minimum year for the above phenomena about 1913 and a maximum about 1915 or 1916.

It is impossible at this early stage of this investigation to attempt to give a definite explanation for the remarkable correspondence observed between the above curves. However, as previously represented by the writer, these pendulum movement are partly due to changes of atmospheric pressure, during the eastward movement of the great cyclonic and anti-cyclonic areas across the western portion of this continent; to the loading of the coast by the ocean tides; to heavy precipitation on the mountains; and to local and other temperature conditions.

Apart from these and, doubtless, other influences, these pendulum movements appear to indicate the presence of some great and mysterious forces ever active on or within the earth.

The marked relationship between the periods of maximum seismic frequency and the extreme movements of the pendulum suggests that the earth is then undergoing abnormal strains, and quakes are more likely to occur at such times along the lines of weakness in the earth's rock mantle.

During these critical periods of maximum earth unrest, it seems possible that movements of the rock strata, though small and slow in action, may be sufficient to permit abnormal escapements of gas into a mine.

The latter, if not detected in time, only awaits the far too numerous forms of ignition, to bring about an explosion, and if aided by dust, may frequently cause a far-reaching catastrophe.

Other movements of the rock strata are doubtless caused by earthquakes of comparatively local origin.

The writer is pleased to announce that from a careful study of curves derived from the horizontal pendulum (which through the generous action of the Western Fuel Company has been working in their mine at Nanaimo at a depth of 979 feet below the surface), the daily curve in a large measure parallels the surface movements here at Victoria, and clearly demonstrates the presence of slow earth movements at this great depth.

It is gratifying to note that the Seismological Service of Russia has recently been granted a large sum of money, not only for the recording of earthquakes, but for special investigations, including "the connection between seismic disturbances and the liberation of firedamp."

As the Province of British Columbia is most favourably situated for the study of these phenomena, it is the writer's earnest intention to devote as much time as possible to the further development of this most important subject, and he hopes before long to present other valuable data which will throw more light upon what has already been brought to the attention of the Institute.

COAL RESOURCES OF THE UNITED STATES.

By Edward W. Parker, Washington, D.C.

(*Annual Meeting, Toronto*, 1912.)

The coal fields of the United States are scattered through thirty different States and Territories. The total area of the known fields aggregates approximately 310,000 square miles. In addition to these known areas there are about 160,000 square miles of which little is known, but which may contain workable coal, and about 32,000 square miles where coal probably exists but under such heavy cover that it is not considered available as a present resource. The map shows how these coal areas are distributed. Geologically, with the exception of small triassic areas in Virginia and North Carolina, the coals in the eastern half of the United States are of carboniferous age. Most of the coals in what is designated as the Great Plains and Rocky Mountain fields are of cretaceous age, and those of the Pacific coast are tertiary. The first coal mined in the United States was from the small triassic area lying near Richmond, in Virginia. This region is now of relatively insignificant importance. No coal has been mined there for several years although attempts are now being made to resuscitate the industry.

Before discussing the bituminous coal areas I should like at the outset to call attention to the famous anthracite coal fields in the eastern part of Pennsylvania. These fields have a combined area of 480 square miles and are estimated to have contained 21,000,000,000 short tons when mining began, but, according to geologists, this represented only 6 per cent. of the original contents of the field, 94 per cent. having been carried away by nature's wasteful action before man began his onslaught upon her wealth. Some coal was produced in this region during the latter part of the 18th century. The first record of coal

COAL MAP OF THE UNITED STATES, COMPILED BY U. S. GEOLOGICAL SURVEY.

production was made in 1814, but the industry is generally considered to date from 1820, when 365 long tons — one for every day in the year—were shipped from the Lehigh region. The total production from this small region has amounted to 2,180,334,670 short tons, or a little over one-fourth of the total output of coal in the United States.

In the early days of mining in this region 1½ tons of coal were lost for every ton produced, and careful estimates have placed the actual exhaustion as about double that of the total production. Not more than ten years ago it was estimated that at the rate of production at that time the anthracite fields of Pennsylvania would last not more than 100 years, but mining methods have been so improved and so much thought is being taken of the conservation of this supply for the future, that it is safe to say the expectancy has been extended 100 per cent.

From the producing standpoint the coal fields of the Appalachian region are at present the most important. This region, which extends from western Pennsylvania on the north to central Alabama on the south, and includes besides those States the areas of Ohio, Maryland, Virginia, West Virginia, eastern Kentucky, Tennessee, and Georgia, embraces 69,332 square miles and is estimated to have contained approximately 542,500,000,000 tons when mining began. Its production in 1910 amounted to 288,000,000 tons. In this area are included the highest grades of bituminous coal found in the United States. Coking coals exist throughout the entire extent of this region, but most of the coke is made from the coals mined along the eastern border. The coking qualities seem to disappear toward the western border of the field. In the far northern areas we find the steaming coals known in the New York markets as "Clearfield," which obtains its name from the fact that it is mined in Clearfield and adjacent counties. In the southwestern part of Pennsylvania, in Fayette, and Westmoreland counties is the famous Connellsville coking district. A little to the west of this, in Allegheny and Washington counties, are the Allegheny steam and the Youghiogheny gas coals. Across the State line in Ohio are found the celebrated Massillion domestic

coal, and further south, the steam coals known to the trade as "Hocking." Some of these Ohio coals are used raw in the blast furnaces, but when so used they are generally mixed with coke. In Maryland and in the adjacent counties of Virginia are found the world renowned Cumberland smithing coal. The coals of the northern part of West Virginia are used chiefly as steam coals. In the southern part of the State occur the high-grade smokeless steam and coking coals, known as New River and Pocahontas, and to the west of these are the famous Kanawha splint and gas coals. In eastern Kentucky is a coking-coal field which is now being opened and promises to rival in importance that of the Connellsville. In Tennessee and the southern part of eastern Kentucky a high-grade steaming and domestic coal is found to which the name of "Jellico" has been given. Alabama is one of the important coke-producing States, and there, in the vicinity of Birmingham, so favourable are the conditions that iron may be made more cheaply than at any place in the world. The ores of iron, the limestone, and the coking coals all occur in close proximity, and one company has its iron, its limestone, and its coal all on its own property, all within a radius of three miles. In the Interior Province, east of the Mississippi, are the coal fields of Illinois, Indiana, and western Kentucky, and west of the river, the coal fields of Iowa, Kansas, Missouri, Arkansas, Oklahoma, and Texas. The coals possess practically no coking qualities. As a usual thing they are not so high-grade, even for steaming and domestic purposes as are the coals from the Appalachian Province, although some coke is made in the southern end of the eastern Interior region, in Kentucky, and small quantities have also been made in Kansas and Oklahoma. On the eastern edge of this area, in the vicinity of Brazil and Terre Haute, Indiana, occurs a coal of unusual quality known as "Brazil block," deriving its name from the regular rectangular blocks into which it breaks. This coal has been used raw as a furnace fuel. It is of about the same age as the Ohio coals, used in iron furnaces. In the area extending eastward from the southern part of the Western Interior region a coal is found which approaches anthracite in quality. This is the semi-

anthracite product of Arkansas. It burns with a short hot flame, and is highly prized as a domestic fuel.

The total area of the coal fields of this Interior Province is something over 100,000 square miles, and the production in 1910 was about 95,000,000 tons, less than one-third that of the Appalachian Province.

It will be observed that the coal fields of the Rocky Mountain and Great Plains region are widely scattered. The principal coking coal field of all this region is the Raton-Trinidad field in the southeastern part of Colorado, and the northeastern part of New Mexico. The coals of these regions grade from the lignite into the true bituminous coals as they approach the mountains. There are two localities in which anthracite is found—at Ruby, Gunnison County, Colorado, and near Socorro, Socorro County, New Mexico. In these cases the anthraciting has been of an entirely local nature and due to the intrusion of heated material near or through the coal beds. At one mine anthracite and bituminous coals are brought from the same opening. After we leave the Rocky Mountain region there is no occurrence of coal known until the Pacific Coast is approached. The most important coal fields of the Pacific States are those of Washington. Some of them contain coking coals, and coke has been made at Carbonado and Wilkeson, in Pierce County, not far from the city of Tacoma. The ovens at Carbonado have been idle for several years. One of these areas, the Roslyn field, lies to the east of the Cascade Range, and some of the highest grade coal of the State is produced in that somewhat isolated field.

Most of the coal produced in California has been from sub-bituminous mines not far from San Francisco, in Alameda, and Contra Costa counties. Some of the true bituminous coals occur about 200 miles to the southeast of San Francisco, but their development has been retarded by the great influx of fuel oil from the wells of California.

Mr. S. A. Taylor, in his presidential address before the Coal Mining Institute of America, at Pittsburg, in December, gave some estimates of the present coal supplies of the world. Those of the United States, exclusive of Alaska, amount to

something over 3,000,000,000,000 tons. So little is known of Alaska that it is hazardous to make any estimates of its fuel supplies, but they can be put down certainly as 150,000,000,000 tons, making the total for the United States still about 3,200,000,000,000 tons. According to the estimates of the Royal Commission on Coal Supplies, Great Britain has a little over 160,000,000,000 tons. Including brown coals and lignites, Germany has 145,000,000,000 tons; Austria-Hungary, France, and Belgium has each from 16,000,000,000 to 17,000,000,000 tons, and Russia about 20,000,000,000 tons. Canada's supplies are placed at 100,000,000,000 tons. The total supplies of all of Europe, according to the above estimates, are 375,000,000,000 tons, or about one-eighth of that of the United States.

INTERNATIONAL COAL COMPETITION.

By Allan Greenwell, F.G.S., Editor of the *Colliery Guardian*, London, Eng.

(*Annual Meeting, Toronto,* 1912.)

A careful and dispassionate study of the literature and statistics relating to coal must inevitably lead to the conclusion that the only sure road to a nation's commercial supremacy lies in the direction of its possessing an unlimited quantity of cheap coal. In this connection the expression "unlimited quantity" is used as meaning practically—not literally—unlimited; that is, a quantity beyond the use which can in any, or at least in present, circumstances be made of it. The term cheap is employed in the sense that the coal can be put upon the market at a relatively low price, regard being had to suitability and efficiency.

It is unnecessary to recapitulate the principles of political economy according to which, except in the case of primitive communities, a country, instead of attempting to produce all its own requirements, directs its attention towards fostering those industries in the prosecution of which it possesses the greatest natural advantages, exchanging its surplus production with other countries for those commodities in the production of which they are better able to compete. A country thus imports that which it is incapable of, or unwilling to, produce, either wholly or in part, and exports that which it can most conveniently produce. Allied to this fact is the fundamental principle in foreign trade that imports must, directly or indirectly, be paid for by exports.

So if the natural course of trade is allowed free play, a country will inevitably produce for itself and for other countries that in which it has the greatest relative advantage (or least disadvantage). If this product be coal, it will tend towards monopolising the production of coal, and to causing the countries which previously produced it to direct their labour and

capital towards the production of something else in which they have an advantage.

The value of a commodity is a matter of supply and demand; so if a country possesses an unlimited supply and can export cheaply a commodity for which there is a considerable demand, it may be said to be on the high road to commercial prosperity.

An article to be exported must, necessarily, first be produced, and the three great agents of production are generally accepted as being "land (which is taken as representative of Nature and natural resources generally), capital, and labour" —and the greatest of these is labour. Material production simply puts utilities into material things or adapts them for consumption, and the act of production is not complete till the commodity is in the hands of the consumer.

The inherent value in coal which constitutes it a commodity in universal demand, consists in its being itself an agent of production, being accumulated potential force. Taking 2 lb. of coal as being equivalent to 1-horse power hour, and 1-horse power as equivalent to 6-man power, then 1 ton of coal is equivalent to the labour of 672 men for one day of 10 hours.

The importance of this statement will be appreciated when it is remembered that in order to make labour efficacious it must be applied at the place where it is required, and under the required conditions.

A steamship of 20,000 tons displacement travelling at 10 knots per hour would consume about 130 tons of coal per day, equivalent to the labour of nearly 87,000 men, if such labour could be efficiently employed on board a ship. The total tonnage of the world's shipping, as recorded by *Lloyds' Register*, is 43,147,154 tons, of which 38,781,572 tons is steam. The estimated population of the world is 1,800,000,000, and deducting four-fifths for women, children and infirm, and employing the above proportion, it would take half the able-bodied male population of the world to man the present steam-driven navigation.

This illustration of the enormous economic value which coal now possesses, also draws attention to the fact that this value was only potential before the invention of the steam engine.

Such being the case, it is not surprising that the enormous annual increase in the production of coal should have begun within the last 100 years. Early statistics of the world's coal production are difficult to obtain, but a comparison of those of the United Kingdom, which even about the years 1858-1860 raised approximately three-fifths of the world's total production, are significant:—

	Millions of tons.
1860	80
1870	110
1880	145
1890	182
1900	225
1910	264

For present purposes it will be unnecessary to go back further than to 1875, which is near to the commencing year of the table of the world's production of coal compiled by the *Colliery Guardian* in January, 1905, for the Royal Commission on Coal Supplies, and printed in their Final Report, part xi., p. 48-9. According to the figures given in this table and from the Coal Tables, 1910, the following table is compiled:—

TABLE A.—WORLD'S PRODUCTION OF COAL 1875-1910, IN THOUSANDS OF TONS (2,240 LB.).

	1875.	1885.	1895.	1905.	1910.
Great Britain	133,306	159,351	189,661	236,129	264,433
United States	46,686	99,069	172,426	350,821	447,837
British North America	929	1,715	3,106	7,739	11,425
Commonwealth of Australia	1,370	3,096	4,290	7,494	9,759
New Zealand	——	511	727	1,586	2,197
India	648	1,293	3,540	8,418	12,047
Germany	37,436	58,320	77,897	119,350	150,372
France	16,686	19,198	27,140	34,652	37,254
Belgium	15,011	17,438	20,121	21,506	23,532
Russia	1,674	4,549	8,846	18,368	22,650
Austria	4,550	7,379	9,567	12,383	13,553
Hungary	635	956	1,051	1,071	1,281
Cape of Good Hope	——	15	77	147	88
Natal	——	——	158	1,129	2,295
Orange Free States	——	——	——	106	504
Transvaal	——	——	1,012	2,327	3,549
Sweden	64	174	220	317	298
Spain	694	919	1,711	3,152	3,751
Japan	572	1,294	4,767	14,818	15,286
Total world's output.	277,531	401,323	——	——	1,035,000

From the above table it will be seen that during the period of 35 years, from 1875 to 1910, the world's coal production has been nearly quadrupled. In 1875 the only countries producing more than 1 million tons per year were:—

	Million tons.
Great Britain	133¼
United States	46¾
Germany	37½
France	16¾
Belgium	15
Austria	4½
Russia	1¾
Australia	1¼
Canada	1

Of these Great Britain contributed approximately one-half of the world's supply, the United States one-sixth, and Germany one-eighth.

By 1910 the United States had increased her production nearly ten times, contributing nearly one-half of the world's supply; Great Britain had only doubled her production, contributing now only one-quarter of the world's supply; Germany had increased her production four times, contributing one-seventh of the world's supply; whilst the other countries named above as producing at least a million tons in 1875, had increased their output as follows:—

	Million tons.
France	37¼
Belgium	23½
Russia	22¾
Austria	13½
Canada	11½
Australia	9¾

In addition to these, several countries which raised less than one million tons in 1875, increased their production by 1910, as follows:—

	Million tons.
Japan	15¼
India	12
Spain	3¾
Transvaal	3½
Natal	2¼
New Zealand	2¼
Hungary	1¼

The increased production of Japan from 572,000 tons in 1875 to 15¼ million tons in 1910 is particularly noticeable.

In its relation to international coal trade a coal-producing country comes at any definite period within one or other of three main categories, although it may come within a different category at different periods. These categories are—

1. Home production is less than home consumption. Balance imported.

2. Home production is just equal to home consumption.

3. Home production exceeds home consumption. Balance exported.

There are, in addition, the cases in which a country imports coal as a convenient return cargo and afterwards exports it, and also those cases in which it exports a part of its own coal production and imports other coal more suitable for its particular requirements.

For the immediate purpose of this paper it will be sufficient, however, to consider the coal trade of a country, from an international point of view, as the excess of its exports above its imports, or of its imports above its exports, as the case may be.

The following table (B) gives the excess of imports (+) or exports (—) of coal into or from the principal countries, from 1885 to 1910, in thousands of tons (2,240 lbs.)

TABLE B.

	1885.	1895.	1905.	1910.
United Kingdom ...	—30,766	—42,893	—67,112	—84,494
British India	+ 805	+ 706	— 649	— 546
Canada	+ 1,306	+ 1,714	+ 5,193	+ 7,945
Australia	— 1,082	— 1,320	— 2,018	— 2,522
New Zealand	+ 81	+ 15	+ 46	— 45
Cape of Good Hope	+ 98	+ 108	+ 381	
Natal	— ?	— 64	— 594	— 1,247
Orange Free States	— ?	— ?	+ 4,000	
Transvaal	— ?	— ?	— 107	
Russia	+ 1,793	+ 2,194	+ 4,291	+ 4,779
Sweden	+ 1,162	+ 1,973	+ 3,429	+ 4,563
Germany	— 7,334	— 8,288	—12,634	—20,146
Belgium	— 4,406	— 4,318	— 1,845	+ 318
France	+10,023	+ 9,730	+11,262	+17,607
Spain	+ 1,456	+ 1,834	+ 2,407	+ 2,467
Italy	+ 2,991	+ 4,220	+ 6,296	+ 9,117
Austro-Hungary ...	+ 1,805	+ 4,479	+ 5,860	+ 9,756
Japan	— 572	— 1,776	— 2,164	— 2,590
United States	— 450	— 2,457	— 7,540	—13,022

The figures given in the foregoing table are most instructive. During the period of 25 years (1885-1910), all the countries which were exporting coal in 1885 had considerably increased their trade in this respect by 1910, with the single exception of Belgium, which had converted an export of 4½ million tons in 1885 to an import of little more than ¼ million tons in 1910. The United Kingdom had increased from 30¾ million tons to 84½ million tons, Germany from 7¼ million tons to 20¼ million tons, the United States from ½ million tons to 13 million tons, Australia from 1 million tons to 2½ million tons, and Japan from ½ million tons to 2½ million tons. South Africa, which probably, on balance, imported in 1885, exported 1¼ million tons in 1910. India had converted an import of ¾ million tons into an export of ½ million tons, and New Zealand an import of 81,000 tons into an export of 45,000 tons.

On the other hand, Canada had increased her imports of coal from 1¼ million tons to 8 million tons; Russia, from 1¾ million tons to 4¾ million tons; Sweden, from 1¼ million tons to 4½ million tons; France, from 10 million tons to 17½ million tons; Spain, from 1½ million tons to 2½ million tons; Italy, from 3 million tons to 9 million tons; and Austro-Hungary, from 1¾ million tons to 9¾ million tons.

The question of the exports of coal from each country is, however, complicated by the fact that the published returns do not in all cases show the procedure with regard to what is called "bunker coal." The total quantity of coal shipped from the United Kingdom for the use of steamers in the foreign trade in 1910 was 22½ million tons, and is included in the 84½ million tons shown in the preceding table. The figures given in the table for France and Belgium are also inclusive of coal for the use of steamers engaged in the foreign trade, while coal for the use of steamers engaged in the coasting or river trade is excluded. In the United States, coal shipped for the use of steamers engaged in the foreign trade is not included in the exports. The quantity of such coal shipped at ocean ports amounted to 5,797,567 tons in 1898, to 5,885,744 tons in 1909, and to 6,193,852 tons in 1910; and at lake ports, 226,162 tons in 1908, 233,400 tons in 1909, and 251,741 tons in

1910. The principle in Germany prior to March 1, 1906, was to exclude all coal put on board vessels to be used as bunker coal, from the import and export accounts. It should, however, be pointed out that coal sent from other ports of the German Empire to the free port of Hamburg was included amongst exports prior to March 1, 1906, and whilst it is true that the greater part of this found its way abroad, a portion may, no doubt, have done so in the form of bunker coal. In later years the German coal supplied as bunkers to foreign vessels is included in the exports, while that supplied to German vessels is excluded. The amount recorded as shipped for the use of foreign vessels has been small, only amounting to between 170,000 and 185,000 tons per annum. In Japan, coal for ships' use was included in the exports up to the year 1900, but excluded in subsequent years. (Coal Tables, 1910.)

A careful examination of statistics goes to show that the bulk of exported coal is employed for navigation purposes. In the case of the United Kingdom, Mr. D. A. Thomas, in his classical paper on "The Growth and Direction of our Foreign Trade in Coal during the Last Half-Century," read before the Royal Statistical Society in 1903, expressed the opinion that over half of our exports are for navigation purposes, and that the quantity of coal supplied to other countries for purely manufacturing purposes does not amount to 4 per cent. of our exports.

This interpretation of the export figures places quite a different aspect upon the question from that popularly accepted; and it reconciles the fundamental law that a coal-driven industry tends to follow the fuel, and not the fuel the industry. From its very nature, navigation must form an exception to this law, as also industries such as the raising of mineral ore, vine-culture, etc., whose location is fixed by superior local advantages. It would therefore appear that coal, as an article of export, should be primarily considered as the "genius" of navigation, for which purpose it has to be conveyed to convenient coaling ports and stations. When required for manufacturing purposes, the industry will tend to seek the coal.

It is thus that a country possessing an unlimited supply of cheap coal can send out its surplus coal to fetch raw material,

which it manufactures cheaply by means of its cheap coal, market the surplus, and pile up wealth.

The prosperity of a manufacturing country is largely indicated by its consumption of coal; and if it can increase its net export of coal at the same time that it increases its consumption, it is, indeed, a happy country.

TABLE C.

	1885.		1895.		1905.		1910.	
	Home.	Foreign.	Home.	Foreign.	Home.	Foreign.	Home.	Foreign.
United Kingdom	128,585	——	146,754	14	168,968	49	179,891	48
India	1,293	806	3,459	787	7,582	187	11,157	344
Canada	1,217	1,734	2,114	2,708	6,297	6,635	9,358	10,012
Australia	?	?	?	?	5,468	9	6,928	277
New Zealand	467	125	641	101	1,463	170	1,920	233
Cape of Good Hope .	15	98	77	108	147	381		
Natal	?	?	94	——	533	2	5,128	61
Orange Free States .	?	?	?	?	57	53		
Transvaal	?	?	?	?	2,155	66		
Russia	4,183	1,797	8,838	2,202	18,308	4,351	22,554	4,875
Sweden	171	1,162	220	1,973	317	3,429	297	4,564
Germany	47,459	2,590	63,764	5,845	96,127	10,589	117,974	12,252
Belgium	11,498	1,254	13,699	2,104	14,850	4,811	16,455	7,395
France	18,260	10,526	25,945	10,925	32,546	13,368	35,602	19,259
Spain	900	1,460	1,703	1,842	3,150	2,409	3,746	2,472
Italy	——	2,909	——	4,236	——	6,334	——	9,164
Austro-Hungary	7,522	2,484	9,792	5,305	12,090	7,224	13,733	10,857
Japan	712	10	2,922	1,226	9,302	352	12,490	204
United States	97,978	822	168,743	70	341,632	1,649	432,566	2,249

The preceding table (C) gives the quantities of coal of home production, and coal the produce of all other countries consumed in the principal countries of the world from 1885 to 1910, in thousands of tons (2,240 lb.).

Referring to Table B, it will be seen that, in the year 1910, of the coal-producing countries of the world only eight showed a balance of exports above imports:—

	Millions of tons.
United Kingdom	84½
Germany	20¼
United States	13
Japan	2½
Australia	2½
South Africa	1¼
India	½
	124½

This total of 124½ million tons is about 12 per cent. of the world's production in that year, 1910 (Table A). Of this quantity the United Kingdom contributed about two-thirds, Germany about one-sixth, and the United States about one-tenth.

The following tables show in what manner the exports were distributed:—

COAL EXPORTED FROM THE UNITED KINGDOM IN 1910, DISTINGUISHING THE PRINCIPAL COUNTRIES TO WHICH EXPORTED.

	1,000's of tons (2,240 lb.).
Russia	3,265
Sweden	4,151
Norway	2,121
Denmark (including Iceland, Greenland and Faroe Islands)	2,941
Germany	9,023
France	9,754
Spain	2,216
Italy	9,060
Egypt	2,617
Brazil	1,710
Argentine Republic	2,921
Other countries	14,743
Shipped for the use of steamers engaged in the foreign trade	19,526
	84,048

COAL EXPORTED FROM GERMANY IN 1910, DISTINGUISHING THE PRINCIPAL DESTINATIONS TO WHICH EXPORTED.

	1,000's of tons (2,240 lb.).
Belgium	4,721
France	4,046
Holland	5,859
Austro-Hungary	9,710
Russia (except Finland)	1,277
Switzerland	2,169
Other destinations	2,104
	29,886

COAL EXPORTED FROM THE UNITED STATES IN THE YEAR ENDED JUNE 30, 1910, DISTINGUISHING THE PRINCIPAL COUNTRIES TO WHICH EXPORTED.

		1,000's of tons (2,240 lb.).
Canada		10,809
Mexico		850
Cuba		822
Other countries		1,759
Shipped for the use of steamers engaged in the foreign trade:		
Ocean ports	6,057	
Lake ditto	239	
		6,296
		20,536

COAL EXPORTED FROM JAPAN IN 1910, DISTINGUISHING PRINCIPAL DESTINATIONS.

	1,000's of tons (2,240 lb.).
Kwangtung Province (Southern Manchuria)	32
China	1,103
Korea (Chosen)	50
Hong Kong	862
Philippine Islands	158
Dutch East Indies	64
Straits Settlements	307
British India	28
Australia	31
United States	63
Other countries	96
Shipped for the use of ocean-going vessels	2,140
	4,934

COAL EXPORTED FROM AUSTRALIA IN 1910, DISTINGUISHING THE PRINCIPAL COUNTRIES TO WHICH EXPORTED.

	1,000's of tons (2,240 lb.).
New Zealand	228
Straits Settlements	141
Hong Kong	10
India	68
Java	92
Chili	553
United States	202
Philippine Islands	200
Hawaiian	64
Other countries	144
"Bunker" coal	1,129
	2,831

COAL EXPORTED FROM BRITISH SOUTH AFRICA IN 1910, DISTINGUISHING THE PRINCIPAL COUNTRIES OF DESTINATION TO WHICH EXPORTED.

	1,000's of tons (2,240 lb.).
India	21
Australia	2
Ceylon	4
Straits Settlements	6
Mauritius	5
Zanzibar	4
Kerguelen Islands	3
Reunion Islands	3
German East and South-west Africa	3
Portuguese East and West Africa	85
Other countries	2
"Bunker" coal	1,336
	1,474

COAL EXPORTED ON PRIVATE ACCOUNT BY SEA FROM BRITISH INDIA IN THE YEAR ENDED MARCH 31, 1910, DISTINGUISHING THE PRINCIPAL COUNTRIES TO WHICH EXPORTED.

	1,000's of tons (2,240 lb.).
Ceylon	371
Straits Settlements	174
Natal	1
Aden	3
Sumatra	79
Australia	121
Other countries	11
	760

From these tables it will be observed that about a quarter of the exports is accounted for by the quantity of coal shipped for ocean-going steamers, principally in the foreign trade, from the United Kingdom, United States, Japan, Australia, and South Africa. As already stated, in recent years the German coal supplied as bunkers to foreign vessels is included in the exports, while that supplied to German vessels is considered as home consumption. Bearing these facts in view, it is probable that, as in the case of the United Kingdom, the bulk of the export coal is employed solely for navigation purposes.

The next inference to be drawn from these tables is that the markets for coal tend to form groups. In Mr. D. A. Thomas's paper on "Coal Exports," already referred to, he delineates 10 groups as follow:—

1. French seaboard at Mediterranean coast.

2. Seaboards of North Russia, Sweden, Norway, Denmark, Germany, Holland, Belgium, Iceland and Whale Fisheries.

3. Brazil, Uruguay and Argentine Republic.

4. West Coast of Africa, Ascension and St. Helena.

5. British South Africa.

6. Indian Continent.

7. Ceylon, Straits Settlements, Java and other Dutch Possessions in India, Philippine Islands, Siam, Hong Kong, China, Japan, Australasia and Pacific Islands.

8. British North America, United States (Atlantic), British West Indies, Bermudas, Foreign West Indies, Mexico, Central America, Colombia and Venezuela.

9. Peru, Ecuador, Chili, Bolivia and United States Pacific.

10. East Coast of Africa, Mauritius and Dependencies, Bourbon, Arabia, Persia, Aden, &c.

Writing in 1903, Mr. D. A. Thomas remarked upon the circumstances of these groups, the following being a short summary:—

Group 1.—British coal had hitherto virtually held a monopoly, and had encountered no serious competition. If competition came, it would probably be from the United States.

Group 2.—British coal meets with German competition.

Group 3.—Is practically a British market; America the only likely competitor.

Group 4.—Virtually a British monopoly.

Group 5.—British coal competes with Natal coal.

Group 6.—Practically no market for British coal. Japanese and Australian coal competes with Indian coal.

Group 7.—Indian, British, Japanese and Australian coals compete.

Group 8.—Principally a United States market.

Group 9.—British, Canadian and Australian coal compete.

Group 10.—No details.

The foregoing remarks apply to the export of coal to the destinations named, by sea only.

The following table (D) employs the same grouping of destinations (with the exception that, for convenience, the whole of Russia is included under Group 2, Denmark is added to Group No. 2, and Switzerland is added to Group No. 1), but the whole quantity exported to the countries named in 1910, whether by sea or overland, is taken into account.

TABLE D.

	United Kingdom.	Germany.	United States.	Japan.	Australia.	South Africa.	India.
1. France, Channel Islands, Portugal, Azores and Madeira, Spain and Canaries, Gibraltar, Italy, Malta, Egypt, Austria-Hungary, Greece, Bulgaria, Roumania, Turkey, Tripoli, Tunis, Algeria, Morocco, Switzerland, etc.	23,647	13,756	—	—	—	—	

TABLE D.—Continued

	United Kingdom	Germany	United States	Japan	Australia	South Africa	India
2. Russia, Sweden, Norway, Denmark, Germany, Holland, Belgium, Iceland, Whale Fisheries and Denmark.	21,501	14,026	——	——	——	——	
3. Brazil, Uruguay and Argentine Republic.	4,631	——	——	——	——	——	
4. West Coast of Africa, Ascension and St. Helena.	——	——	——	——	——	88	
5. British South Africa.	——	——	——	——	——	——	1
6. Indian Continent.	——	——	——	28	68	21	
7. Ceylon, Straits Settlements, Java and other Dutch Possessions in India, Philippine Islands, Siam, Hong Kong, China, Japan, Australasia and Pacific Islands.	——	——	——	2,607	671	12	745
8. British North America, United States (Atlantic), British West Indies, Bermudas, Foreign West Indies, Mexico, Central America, Colombia and Venezuela.	——	——	12,481	——	——		
9. Peru, Ecuador, Chile, Bolivia, and United States (Pacific).	——	——	——	63	819		
10. East Coast of Africa, Mauritius and dependencies, Bourbon, Arabia, Persia, Aden, etc.	——	——	——	——	——	15	3
	49,779	27,782	12,481	2,698	1,558	136	749
Other countries	14,743	[illegible]	1,759	96	144	2	11
"Bunker"	19,526	——	6,296	2,140	1,129	1,336	——
	84,048	29,886	20,536	4,934	2,831	1,474	760

Considered from this point of view, the figures present an interesting and instructive aspect, for they tend to show that the spheres of competition in regard to the exportation of coal are fairly well defined and easily understood.

Group.	Area.	Foreign supply from—
1 & 2.	Europe and Mediterranean Coast.	United Kingdom and Germany.
3.	South America (Atlantic)	United Kingdom.
4.	Africa (West Coast)	South Africa.
5.	Africa (Cape)	India.
6.	India	Japan, Australia, South Africa.
7.	Far East	Japan, Australia, South Africa, India.
8.	Canada and United States (Atlantic)	United States.
9.	Canada, United States and South America (Pacific)	Japan and Australia.
10.	Africa (East Coast)	South Africa and India.

The conditions governing competition in the export of coal to any particular area may be divided into three classes:—

1. Permanent (within limits).
2. Inherent, but capable of gradual change.
3. Temporary.

In the first class are included the available supply of coal possessed by the country, the cost of working, the relative economic value of the fuel, and the distances of the coalfields from the market. In the second class are the general physical and technical efficiency of the miners and operators, the national moral character of the people in their business relations, currency and national business methods, and the existence of an incentive to develop a coal industry.

In the third class are such circumstances as the trend of trade, Government tariffs and restrictive legislation, labour and capital combinations, political disturbances, variable seasons, &c.

The following estimate of the coal area still unworked was made by M. E. Lozé in 1901 (Final Report of the Royal Commission on Coal Supplies, Part xi., p. 34):—

	Square miles.
China	232,500
United States	200,000*
Canada	65,000†
India	35,000
New South Wales	24,000
Russia in Europe	20,000
United Kingdom	12,000
Spain	5,500
Japan	5,000
France	2,500
Austria-Hungary	1,800
Germany	1,700
Belgium	500
Total	605,500

The peculiar fact that enormous coal areas, such as those of China, should remain undeveloped can only be accounted for by the want of incentive. In the same way the rich coalfields of Western Canada are only recently receiving attention. Apart from other sources of wealth, such as fisheries, ore deposits, &c., Canada possesses boundless areas of the most fruitful agricultural land in the world, of which only a small percentage is as yet under cultivation. With a population of only about 7½ millions she has an enormous surplus of agricultural produce to export, for which there is a still greater demand. The history of the coal industry in the United States must have been somewhat similar. In the first edition of Mr. (now Sir) Edward Hull's book entitled "The Coalfields of Great Britain, their History, Structure and Duration, with Notices of the Coalfields of other Parts of the World," published in 1861, the author says:—

> The annual quantity of coal raised in the United States is about 5 millions of tons. If to this we add 1 million for the produce of the coal fields in the British possessions (Canada), we have a total for the whole of America of 6 millions of tons. Now, taking the area of these coalfields at 204,000 square miles, and comparing it with that of the English coalfield—2,779 square miles—we find that the former is 72 times larger than the latter, but the quantity of coal raised in America is only one-tenth the amount raised in England and Wales. In other words, if the coalfields of

*The coalfields of the United States include an area of about 496,480 square miles. [Mines and Quarries: General Reports and Statistics for 1909, Part IV. Colonial and Foreign Statistics, p. 456.]

†According to estimates prepared by Mr. D. B. Dowling, of the Geological Survey of Canada, the known area underlain by workable coal beds in Canada is 29,957 square miles. [Report of the Commission of Conservation, Canada, on "Lands, Fisheries and Game, and Minerals" for the year 1911, p. 431.]

America, were developed to as great an extent as those of England, they ought to raise 452 millions of tons annually, or 72 times more than at present.

As a matter of fact, the production of coal in the United States in 1910 (Table A) was 448 millions, or practically the same as Sir Edward Hull's estimate.

Applying the same line of comparison to Canada, there is no reason why the enormous coal resources in British Columbia, Alberta and Nova Scotia should not, when their time arrives, be developed to an equal extent with those of the United States.

Jevons has shown conclusively that it is a commercial impossibility for any country to secure or maintain a manufacturing supremacy on coal drawn from far distant fields, and the manifest corollary to this conclusion is that there can be no real or lasting inducement to a country to develop its coal supplies in order to foster a manufacturing industry in another country, especially if it can organize such an industry within itself.

Eventually competitive manufacturing industries must be carried on in the neighbourhood of the coal supplies, and the surplus production of the latter employed for navigation purposes in fetching the raw materials, and in distributing the manufactures.

Hence a large export coal trade will be the surest indication of a great commercial prosperity.

In the course of the preparation of this paper free use has been made of Government statistical publications, and of many works by standard authorities, and the writer wishes to gratefully acknowledge his indebtedness especially to the late John Stuart Mill, and W. Stanley Jevons, and to Mr. D. A. Thomas, and Mr. J. Shield Nicholson.

A short bibliography of works of reference is appended to this paper.

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Discussion.

Dr. J. B. Porter: The Secretary has suggested that I might refer briefly to a matter which, I think, will interest the Institute. It was announced before the Institute two or three years ago that the Department of Mines had made arrangements with myself and certain other persons to prepare a report on the economic aspect of the coal resources of Canada. I am now able to announce that the report, which has been unexpectedly delayed, is now completed and will be shortly distributed. The investigation is searching in respect of the coals mined four or five years ago, but it has been impossible, of course, to keep up with the very rapid development that has since taken place, and consequently reference to certain of the newer mines is either very brief or omitted.

In addition, as a virtual supplement to the investigation above mentioned, I am now engaged on my own account upon the study of the spontaneous combustion of coal in storage, a very important matter in this country, because our transportation being largely by water necessitates the shipment of the main part of our coal supply in the summer months, and we are seriously troubled with fires in the storage piles during the autumn and winter. I should like to ask any member who is interested in the matter and who has any information bearing upon the spontaneous combustion or heating of Canadian coals in store,

to communicate with me, in order that the paper which is being prepared may be as complete as possible.

The Secretary in reading his abstract of Mr. Greenwell's paper makes it appear that Canada is the one important coal-producing country that is importing more coal than it exports, and he commented upon that as being a rather unfortunate circumstance. It is unfortunate, but it is perfectly natural in view of the geographical distribution of the coal in Canada; but a condition that will not probably continue to obtain. The great central part of Canada lacks coal of its own, and consequently draws from the nearest and cheapest source of supply. Furthermore, the higher class demand for domestic purposes is for anthracite. The nearest anthracite in Canada is 2,000 miles distant; the best anthracite in the United States is 200 miles distant.

In addition to a very considerable importation of anthracite from the United States, we also draw largely on the coals of Western Pennsylvania, Ohio and the Middle West for the steam coal demand of Central and Western Ontario and Manitoba; but this importation is more or less offset by equivalent exports in the East and Far West. On the whole, however, as Mr. Greenwell says, our imports for the time being are, it is true, greater than our exports, but that will be a very temporary state of affairs. We have on both oceans large coal supplies, and I think it is safe to assume that at a very early date we will be exporting more coal than we import; and we must remember in this country that the very district which lacks coal and obtains its supplies from abroad is richly endowed with peat of an excellent quality, and also with abundant water power. The development of these water powers and peat bogs is bound to be comparatively rapid and will soon render Central Canada largely independent of the United States for all power fuel, although domestic fuel will, no doubt, continue to be imported.

MR. E. W. PARKER: The statement has been made, I believe, that the consumption of coal in the United States is at the rate of three tons per capita. As a matter of fact the consumption is at a rate of rather over 5¼ tons per capita. Sixty years ago our per capita consumption was about a quarter of a ton.

Mr. R. V. Norris: Coal is a low grade product, and consequently costs of transportation have an important bearing on its marketing. The market range for coal must necessarily depend on this consideration and not on national bounds. It is natural, therefore, that Eastern Canada should import Pennsylvania coal and that the Western United States should import Canadian coal. The better deposits of Western coal are in Canada and in Alaska; and the better deposits of Eastern coal are in Pennsylvania and the adjoining States. Hence, in my opinion there is fair reason for reciprocity in this product between the two countries. Such an arrangement would be mutually advantageous.

Mr. J. C. Murray: We have had a good deal of reference to the Western coal fields, but no specific reference to the Eastern coal fields. I have here a memorandum prepared by the Hon. Robert Drummond of Nova Scotia, who has been identified with coal mining for 25 or 30 years. Mr. Drummond traces the history of the development of coal mining in Nova Scotia as compared with coal mining in the United States, and shows that the sales of coal from the entire States now exceeds by 75 times the total sales from Nova Scotia, whereas in the year 1840 they were but ten times greater. Mr. Drummond lays special stress on the high cost of coal mining in Nova Scotia.

FUEL PROBLEMS OF THE PACIFIC.

By H. Foster Bain, San Francisco, Cal.

(*Annual Meeting, Toronto,* 1912.)

Trade routes and trade conditions, it is anticipated, will be profoundly influenced by the opening of the Panama Canal, and in any readjustment of trade the problems of fuel supply are of large importance. The cost of fuel is not only one of the principal elements in the cost of transportation, but the distribution, character, and abundance of fuel determine the character and amount of manufacturing that may be carried on by each of the trading nations. Up to a hundred years ago sea trade was dependent upon wind and tide. Interior commerce at the same time was conducted through the agency of streams or by horse or man power. Under these conditions distribution of food supply and the direction of the trade winds were the main factors in determining the position of the great ports. Less than half a century ago the big ocean trade of California was that in wheat, which was carried to Europe around Cape Horne in sailing vessels. Man is no longer satisfied with having merely enough to eat and something to wear. His wants have multiplied, and to satisfy them large manufacturing enterprises and lines for quick and sure transportation of goods have grown up. Both require expenditure of mechanical energy, and while an increasing part of the load is coming to rest on the water falls, at present the burden of civilization is carried by fuel.

The North Atlantic which has long been the field of a mighty commerce, has abundant and excellent supplies of coal on both sides and this has been an important factor in development of trade. Transportation has been cheaper because steamers could coal on each end of their run and therefore the maximum amount of cargo space was available. On the shores of the south Atlantic no important coal fields have been devel-

oped, though in South Africa, Brazil, and the Argentine, supplies that satisfy in part the local needs have been found. South Atlantic countries are importers of coal, and commerce between them and the United States or Europe must carry the burden of coal freightage.

On the Pacific, until recently, fuel supplies have been inadequate. British Columbia on the one side and New South Wales on the other have been the main sources of supply and, in part as a result of scarcity and high cost, and in part because of trade balances, the actual fuel supply has been derived in considerable part from Europe and the Eastern United States. In Chile, California, Oregon, and Washington coal mines have been opened, but the quality of the coal found has not been altogether satisfactory and the quantity is inadequate to the local demand. An exception to the last statement should possibly be made in favour of Washington, which in recent years has exported 20,000 to 25,000 tons of coal, more than half of which has gone to Alaska. More recently a large coal trade has been built up in Japan, shipments have begun to be made by China, mines have been opened in New Zealand, Victoria, the Dutch East Indies, and the Philippines, and plans have been made to open mines in Alaska. The greatest change made in the Pacific fuel situation has resulted from development of the fuel oilfields of California, but it will be more convenient to consider them separately.

Coal occurs in 43 of the 49 prefectures of Japan, but the principal mines are situated in the south on the island of Kyushu and in the north on Hokkaido. In 1877 the total coal output of the Empire was 491,835 long tons. In 1910 it was 15,681,324. While coal is found in both Mesozoic and Tertiary formations, and varies in grade from lignite to anthracite, that which is principally mined comes from the early Tertiary and is of excellent bituminous grade. Roughly it is the equivalent in character, as it is in age, of the coals of Wyoming and Montana. Coke of good, though not the best grade, can be made from it and it has an excellent reputation for steaming qualities. The beds are of workable thickness, eight to ten feet, and lie well for working, though the pumping problem is often a

serious one. It is difficult to make direct comparisons of cost since the whole basis of payment is so different from that in North American mines. Official statistics place the value of the coal at the pit-mouth in 1910 at $1.61. This corresponds roughly with similar figures for Wyoming in which state the value of the coal mined in 1908 is given by E. W. Parker as $1.62 and in 1909, as $1.55. The corresponding figures for Washington were $2.21 and $2.54. In Japan, as in the United States, such average figures are only of general value. Actually the cost of coal mining varies greatly from colliery to colliery. At one of the big mines of Japan excellent coal is being delivered at the dock at a cost of slightly less than $1 per ton. Thus certain, at least, of the Japanese mines can deliver coal at seaboard for about the same cost that it can be mined in western Pennsylvania and eastern Ohio. Of the total coal output of Japan 64 per cent. is derived from the mines on Kyushu and 52.5 per cent. comes from the mines of the Chikuho districts, delivering to the ports of Moji and Wakamatsu. It is worth noting that of the total output of the mines belonging to the Chikuho Coal Mining Association, 58.5 per cent. is used in Japan, 21.5 per cent. is sold abroad, and 20 per cent. is delivered directly to steamers as bunker coal. The Kyushu mines being situated within a few miles of ports on one of the great trade routes of the world are especially well placed for bunker trade. Wyoming coal to reach San Francisco, for example, must pay a freight rate of $5.50. Japanese coal to reach Nagasaki pays but one or two per cent. of that amount. The net result is that coal is placed aboard ship in Japan for just about one-half the cost at San Franisco. The mines of Hokkaido furnish an excellent coal, one well adapted to making coke and gas-making coals also occur. The fields are less well developed and the output in 1910 was but 1,485,209 tons. Steel and iron industries now being established will make demands upon these fields, but Hokkaido being off the main trade routes, the mines are not likely to secure much of the bunker trade. Japanese home consumption of coal is small, a result of the customs of the people, the general utilization of water power, and the incomplete development of industry. It is roughly 1-6 of a short ton per capita per annum,

which may be contrasted with the average of 5¼ tons per capita in the United States. That this is not a matter solely of climate is shown by the fact that the corresponding annual consumption of coal in the Pacific Coast States is approximately 1 ton per capita, or if the fuel oil burned be reduced to equivalent coal, the amount would be roughly, 3 tons. Taking into full account climatic differences and undeveloped water powers, it is evident that on both sides of the North Pacific consumption of coal may be expected to increase rapidly for many years. The Japanese are much more economical than we are and it is not likely that they will ever consume the same amount of coal per capita as do their Canadian and American neighbours, but wants are increasing rapidly in Japan, and wants mean industries, and factories need coal.

In China conditions are not so advanced. T. T. Read, who has recently reviewed the situation there,* estimates the per capita coal consumption at 1-25 of a ton and the present production at 13,000,000 tons. China is a considerable importer of coal, as are the East Indies and the Philippines. The largest part of the Japanese foreign trade in coal is with these countries and while in each mines have been opened, they do not as yet supply local shipping demands. That excellent coal occurs in many of the provinces of China has long been known, and as Chinese have made money in coal and iron mining there is not that prejudice against these branches of the industry that exists against metal mining. Most of the fields, however, are not near the ocean and lack of transportation has hindered the development of the industry. Railways are being rapidly built and already coal from north China is in active competition with that from Japan at Shanghai and other southern ports. The most important coal-mining company in China is the Chinese Engineering & Mining Co., Ltd., a British concern owning the Kaiping collieries in Chili province and delivering coal to Chinwangtao and Tientsin. This company shipped 1,174,312 tons in 1910. In Manchuria the principal mines are the Fushun collieries, near Mukden. These are under the control of the Japanese and ship coal through Dalny, being the chief com-

* *Mining and Scientific Press*, October 7, 1911.

petitor of the Chinese Engineering and Mining Co., Ltd., in the shipping trade. These two companies are enabled to hold their dominant position largely through the superior shipping facilities they enjoy. The Fushun output in 1910 was 830,328 tons. In Shantung there is a German-controlled mine which in 1910 shipped 252,816 tons, delivering to Tsingtau, and in Kiangsi, at Pinghsiang, there is a Chinese company that in 1910 produced 610,000 tons. The Pekin Syndicate, Ltd., also British, has a colliery in Honan with a capacity of 2,000 tons per day. In 1910, 357,205 tons was shipped. This coal is anthracite and is used both for household and steaming purposes. There are a number of other collieries but all are at a distance from the sea. Chinese harbours are generally poor, and while mining costs, where figures are available, seem to be lower than in Japan, the cost delivered in bunkers through lighters is necessarily higher. Roughly, wholesale prices for coal in the two countries do not greatly differ. At Chinwangtao the price of lump coal is $3.50 to $4; Tientsin, $4.25 to $5.25; Dalny, $4; Hankow, $3.25, Tsingtau, $3.50. In Japanese ports bunker coal can be bought for $4 to $4.50 per ton. An important factor in the competition between Japanese and Chinese coal is that the vessels are commonly equipped with European types of boilers, for which the long flame Japanese coal is better suited than the shorter flame Chinese coals. It is clear that in Japan there is more profit in mining coal for export, and in China even more room for growth of local trade than in Japan. In both countries the coal reserve known and probable, is large, though that of China is much the larger.

Next to Japan the most important factor in the present coal trade of the Pacific is Australia. Coal is found in all the states of the Commonwealth, and in New Zealand, but 85 per cent. of the production comes from New South Wales. In 1910, that state was credited with 8,304,284 of the total of 10,015,214 tons produced. In recent years labour troubles and, it is said, control of prices by a "Coal Vend" have interfered seriously with Newcastle's coal trade. Determined efforts have been made to develop supplies in other fields and a mine has been opened by the state in Victoria, while in Western Australia private

firms have built up a considerable production. For the first eleven months of 1911, according to *The Australian Mining Standard,* coal exports from Australia amounted to £790,328 in value as against £815,952 in the same months of 1910. Apparently the export trade amounts to about 4,000,000 to 5,000,000 tons per annum, though detailed figures for recent years are not at hand. In 1906, New South Wales produced 7,626,362 tons and exported 4,961,540. Of this 1,626,288 tons went to New Zealand and to other Australian states, 710,322 went to South America, 174,146 to the United States including Hawaii, and the remainder to China, the Philippines, and the East Indies. The bunker coal that year amounted to 1,000,000 tons, valued at about $2.25 per ton. These figures may serve to show the relative importance of the different branches of theAustralian coal trade. As to price it can only be said that the pit-mouth value of coal in New South Wales is about the same as in the principal coal-mining states of America, namely $1.25 to $1.75 per ton. Australian coal is not notably better or worse than that with which it comes into competition, and there are undoubtedly large reserves available. The per capita annual consumption of coal in Australia is about one ton. This may be expected to grow. Australian harbours are excellent, and the coal mines are favourably situated to supply a growing export trade.

On the American side of the Pacific, as already indicated, the available coal supplies lie well to the north. In Alaska there are extensive fields of coal. At least two, the Matanuska and the Bering River, contain coal of such a grade and are so situated that they may be expected to contribute to the general coal market. The cost of mining in Alaska will necessarily be higher than in Japan, China, or Australia, and, while the quality of Alaskan coal may give it some advantage in competition with Puget Sound or British Columbia coals, it would, in the main, be at a disadvantage when compared, for example, with Takashima coal. At present Alaska coal is not being mined and the prospect for any immediate activity in coal mining in that territory does not seem brilliant. The whole subject of Alaskan coal has been so thoroughly discussed in technical and other journals in the last few years, that it will be sufficient

to note that coal of good quality and abundant in quantity is available at harbours open the year round and but little more than one day's journey off the great circle route for steamers from Japan to North America.

As matters now stand the most important coalfields upon the Pacific coast of North America are those of British Columbia. When railways now building are completed, the great coal-bearing areas of Alberta will also be tributary to the Pacific. According to estimates of the Commission on Conservation for Canada, the coal reserve of British Columbia amounts to 38,976 million tons and that of Alberta to 104,932 million tons. The present production (1910) is, British Columbia, 3,319,398 tons; Alberta, 2,824,929. As already stated the British Columbia coal alone now gets into the foreign market. In 1909, 678,137 tons was shipped to the United States, 63,500 to other foreign countries, and 998,494 mined for the home market. The annual coal consumption of Canada is about three tons per capita and about half the Canadian supply is imported. The industry may be expected to increase rapidly in importance both to meet local needs and probable foreign demand. British Columbian coal can be made into satisfactory coke and is of such quality that it dominates the North Pacific coal market. I am unable to give figures of the cost of coal mining in British Columbia. In the statistics published by W. Fleet Robertson, the output is valued at $3 to $3.50 per ton. These figures apparently include more than the cost of mining, and as a matter of fact coal mining in British Columbia is known to be thriving and profitable at present selling prices.

In the United States but little coal is mined on the Pacific, outside of Washington. According to E. W. Parker, the production of that state in 1910 was 3,903,983 short tons. In addition 62,707 tons was mined in Oregon and 11,164 in California. The imports amounted to 752,046 tons of bituminous and 9,116 of anthracite coal. A moderate amount of bituminous coal was shipped into the Pacific states by rail, and presumably not counted in the above. In addition coke was imported from China, Germany, Great Britain, and other countries.

The dominant factor in the Pacific coast fuel situation is no longer coal but oil, and of this in 1911 California produced 77,224,359 net barrels. Not all was shipped, and by no means all was used for fuel, but it is estimated that 40,000,000 to 50,000,000 bbl. each year are now burned for fuel, replacing 11,000,000 to 12,000,00 tons of coal. Fuel oil is delivered at tidewater from Alaska to Peru at prices that give it a marked advantage over coal without taking into account the incidental advantages of cleanliness, lower cost of handling, and decreased labour cost in the fire room. Fuel oil is delivered on the Pacific coast at 85c. to $1 per bbl., equivalent to a cost of $3 to $3.50 per ton for coal, considering fuel value alone. The surplus above ground, over 40,000,000 bbl., the extent of territory developed, and the ease with which production is increased, give every assurance of continued supply at reasonable price for years to come. As a result oil has practically replaced coal throughout California, western Arizona and Nevada, and Oregon, and is rapidly gaining a foothold in Alaska, British Columbia, Washington, Mexico, Central and South America. In California coal is now little used except for domestic heating and for bunker purposes on certain steamships that have not yet found it economical to change to oil burners. Practically all the regular coastwise steamers, save some belonging to the Pacific Coast Steamship Company, which company has its own coal mines, now burn oil. The Alaska Steamship Company, the Canadian Pacific, the Grand Trunk, the Oceanic, the Matson, and other lines have adopted oil. It is especially interesting to note that the Oceanic steamers now being rebuilt at San Francisco to run between that port and New Zealand, will burn oil. The steamers of the Toyo Kisen Kaisha on the trans-Pacific run, originally fitted for burning oil, have been altered to burn coal because of the absence of an oil supply in Japan and difficulties over tariff on oil imported into that country. This fact is notable in that it is almost the only instance of a large user of oil going back to coal-burning. The trans-Pacific steamers in general burn coal. The reason for that lies in part in the conservatism of the management, but also in part in the low cost of coal in Japan, low cost of Oriental labour available

in the fire rooms, and excess of cargo space which has permitted Pacific Mail boats, for example, to take coal at Nagasaki for the round trip. In general, however, California oil not only dominates the fuel situation on land along the Pacific coast, but is rapidly being substituted for coal on the sea. On land, for transportation and manufacturing, the most important competitor of fuel oil, is hydro-electric power. Here the race is between low overhead charges and low operating costs, and at competing centres such as San Francisco the two are about in balance. Power from either source may be had as low as a half cent per kilowatt-hour, which places San Francisco about on a par with Chicago so far as necessary cost of power for manufacturing is concerned. Despite the necessity in California for importing coke, and the small population which prevents establishment of large units in manufacturing, it can not be doubted that factories are destined to become increasingly numerous on the West Coast and in California. A climate that permits open air work the year round will offset in part the higher cost of labour. At present 400,000 h.p. equivalent to 10 per cent. of the theoretical possible maximum available in the waterfalls of California, is developed and in use.

It remains to enquire the bearing of this fuel distribution upon the new trade alignment expected to follow the opening of the canal.

At present the trans-Pacific trade is small when measured against the trans-Atlantic or that existing between the Far East and Europe. The trade between Europe and the North Pacific is still smaller. Taking per capita coal consumption as a measure of energy devoted to manufacturing, it is clear that there is large room for expansion in the countries bordering the Pacific, even with the present distribution of population. It is anticipated that establishment of direct steamer lines to Europe will lead to a rapid influx of colonists in Western America and stimulate industrial growth correspondingly. It is also confidently expected that changes in the Far East will lead to a larger and more diversified demand for the products of Europe, the United States, and Canada. At present, for example, the major exchange of commodities between Japan and the United

States consists of trading silk and tea for cotton and kerosene. No one familiar with the two countries can fail to see many other products that might be exchanged to advantage. A larger trans-Pacific traffic may therefore be confidently expected. Apparently it is likely to consist mainly of high-class goods, such as are shipped usually by fast ships belonging to regular lines. Insurance on a valuable commodity such as silk or tea is necessarily so high that speed and certainty of delivery becomes more important than the rate charged for carriage. Trans-Pacific business, as it increases, is likely therefore to fall to the companies that dispatch fast ships regularly. Such ships, as cargo space and speed come to be at a premium, seem likely to be oil-burners and therefore Californian ports will, at least, not be at a disadvantage in competition. The shortening of the railroad haul that will result from the building of the new trans-Canadian line, with development of the Alberta coalfields, will assure Canada a growing share in the trade. Just where the balance will lie can not be foretold.

There is, however, another trade which must be taken into account. The Far Eastern countries buy more goods from Europe than they ship in return. On the other hand they ship more to North America than they buy. In turn, Canada and the United States ship more tons of freight to Europe than they receive in return. There is, therefore, an excess tonnage of freight moving round the world from west to east. After the balanced tonnage on any route is cared for, there remains an excess of carrying capacity in one direction. The economical way to handle this will be by around-the-world ships travelling from Europe by way of the Suez and returning by way of Panama. Such steamers will necessarily travel on a slow schedule with long stops for loading and unloading freight. In part they may be expected to take the great circle route from Japan to Canadian or Puget Sound ports, and in part, with an eye to the Hawaiian freight, they will travel by the southern route. Those that choose the latter will need to replenish their bunkers at Panama, and the active coal market there seems destined to fall to the companies mining in the Virginias, Maryland, and Pennsylvania. How large this market

will prove to be can not be surely foretold, but the Bureau of Statistics of the United States Department of Commerce and Labour has recently estimated the total amount of coal consumed on the ocean at 75 million tons, and as being worth over $250,000,000.

The officials of that bureau state that an exact statement of the quantity of coal consumed by the merchant marine and navies of the world cannot be made, owing to the fact that comparatively few countries state in separate terms the quantity of coal supplied to vessels for their own use, or for "bunkering" purposes. The United States statistics show about 9,000,000 long tons supplied to vessels at ocean ports to be placed in their bunkers for their own use, and the British reports show about 20,000,000 long tons supplied to vessels in the foreign trade and 2,500,000 tons to vessels in the coastwise trade. This would make for the two great coal-producing countries of the world a total of over 30,000,000 tons supplied directly to vessels for "bunkering" purposes. In addition to this, however, a considerable percentage of the coal exported from Great Britain passes to ports and stations in various parts of the world from which it is finally supplied to ocean vessels for fuel purposes. A paper presented before the Royal Statistical Society of England by D. A. Thomas, stated that:

"The great bulk of our export of coal is for the use of steamships, and it is within the mark to say that over half of our exports are for navigation purposes. . . . Cardiff alone ships over a million tons annually to Port Said, over half a million to Malta and Gibraltar, about the same quantity to Cape Verde and the Canaries, over 300,000 to Colombo, and large quantities to Aden, practically the whole of which goes to bunker steam vessels calling to coal at these depots."

"As the British exports of coal," continues the report of the Bureau, "aside from that recorded as supplied to vessels for fueling purposes amounted in 1910 to over 62,000,000 long tons, the above quoted estimate would seem to justify adding to the 30,000,000 tons recorded as bunker coal by the United Kingdom and the United States another 30,000,000 as the share of British exports which finally become bunker coal through pur-

chase for bunkering purposes at ports or stations to which it was originally exported. While the Bureau of Statistics is unable to state the share of American coal exports which become vessel supplies (aside from that actually reported as bunker coal and not included in the export statement) it is quite probable that a considerable percentage of the coal from the United States which passes to the West Indian Islands and the coast of Mexico is used for vessel fueling. Add to this the more than 2,000,000 tons supplied by the Japanese mines to vessels engaged in the foreign trade, the more than 1,000,000 tons supplied from Australia, the nearly 1,000,000 tons supplied from India, plus the estimated consumption of about 3,000,000 tons by the navies of the world, and the Bureau of Statistics estimate of an average of 75,000,000 tons consumed on the oceans of the world seems a conservative one."

These estimates emphasize the importance of the trade in coal for steamship use. Any readjustment in trade lines necessarily requires opening new coal depots and the Panama Canal zone seems certain to become the centre of an extensive coal trade. Japanese and North Pacific coal ports are also certain of increased traffic, the extent of which will depend largely upon the development of the around-the-world traffic already noted. Whether this, or the traffic of regular lines from port to port with transhipment of freight, will grow most rapidly, is not certain. The modern world values speed and certainty highly; and, despite the lower water rate, the bulk of the freight between the Atlantic seaboard and the Pacific coast is now handled by the railways. It may well prove that since in maintaining a regular schedule, liners must often sail with unfilled cargo space, a careful adjustment of rates may give the traffic to the regular lines. Certainly the ports that equip themselves most effectively for transhipping freight and dispatching vessels will have the advantage in the competition. Cutting the canal will reduce distances on several of the great trade routes. This in turn should lower costs and decrease the time in transportation. Both these factors will operate to stimulate industry and increase the demand for fuel. Cargo space eastward across the Pacific will become too valuable to permit Japanese coal to be

regularly carried for the return voyage, though Japanese mines seem certain to do a good business in coaling ships for the North Pacific, Panama, and South America. Enthusiastic Japanese statisticians estimate an increase of trade in sale of coal and water to ships, of over $100,000,000 per annum as a result of opening the canal. Fast boats, burning oil, can load for the round trip at California ports while coal-burning ships from Europe and the Orient will depend upon Puget Sound and Canadian mines for fuel for the return trip or its extension. While the immediate effect of opening the canal will be that the world's freight, being carried on shorter routes, will require the burning of less fuel. This will quickly be offset by the demand incident to a greatly increased volume of traffic.

DISCUSSION.

MR. JAMES WHITE: I am inclined to think that Mr. Bain underestimated the importance of oil in competition with coal as fuel on the Pacific Coast. It is not surprising that railways such as the Santa Fé and Southern Pacific are utilizing oil as locomotive fuel. In addition, the Great Northern, of the United States, is now burning oil on its line crossing the Cascade Mountains, and next summer, oil-burning engines will be employed as far east as Spokane. Again 70 oil-burning engines will be in operation this year on the main line of the Canadian Pacific, between Kamloops and Field, and on the Esquimalt and Nanaimo line. The innovation so far as the Canadian Pacific is concerned is mainly due to recognition of the damages caused by forest fires for which coal-burning locomotives were responsible. I believe, that in the near future oil will entirely replace coal on the main line of the Canadian Pacific between Vancouver and Calgary. On the Crow's Nest route, however, the very considerable difference in cost will probably militate against the adoption of oil fuel; but under the new law, the railways will be responsible for the destruction of property by fires caused by sparks from locomotives. In one suit the Great Northern Railway was oblig-

ed to pay damages to the amount of $31,000. The cost of a few such fires, plus the cost of patrolling the track behind the train, would very soon cover the difference in cost between the use of oil and fuel. This also explains the adoption of oil in place of coal in many instances.

MR. R. V. NORRIS (Wilkesbarre): The reference to anthracite as being sufficiently bituminous to serve for steam purposes is amusing. As a matter of fact about 30,000,000 tons of Pennsylvania anthracite, in the smaller sizes, is used annually for steam raising. Mr. Bain's comments on the coals of the Pacific Coast, recall to my mind an experience of my own in connection with coal mining in the West, which may be worth recounting. In the south-western corner of Monterey, about 200 miles from San Francisco, is a little coal basin. To my sorrow I made a study of it. The basin is on a very steep dip and (for the Pacific Coast) contains coal of a very remarkable quality. It is a bituminous coal, but very high in volatile. The analysis gave about 50 per cent. volatile combustible, about 42 or 43 per cent. fixed carbon, low ash, and moderate sulphur. The dip of the seam was extremely steep, and the coal, which was absolutely homogeneous, appeared almost to be cast in place. The difficulty in mining was occasioned mainly by a very unpleasant footwall of swelling clay, which tended to spontaneous heating on contact with water, firing the very inflammable coal. The coal itself was not susceptible to spontaneous combustion, but where the footwalls were exposed to water fires were frequent. The basin, as stated, was small, the available coal supply being estimated at twenty million tons, although there were possibilities of a supply of fifty million tons or more. The extreme dip and the bad footwall made mining expensive. The workings were at a high altitude, practically unreachable by railways, and consequently it was necessary to design a tramway, with a drop of a thousand feet in a distance of a mile, to transport the coal to the shipping point. The company operating this property failed, but nevertheless there is in this basin an available supply of coal with which in estimating the resources of the Pacific Coast, one may properly reckon.

The effect on the coal industry of oil competition is even more serious than has been indicated. The only present market

for coal on the Coast (at least, within the competitive range of oil) is for domestic purposes. For domestic purposes very fine coal is not suitable, hence there is no market for the smaller sizes, which are practically valueless. While, therefore, the cost of mining is about $1.75 per ton, about 60 per cent. only of the production is marketable.

MR. E. W. PARKER (Washington, D.C.): Last year the consumption of California oil for fuel purposes on the Pacific Coast was approximately 52,000,000 barrels. This was equivalent to the displacement of about 15,000,000 tons of coal. About 21,000,000 barrels were used by the railways; 20,000,000 barrels by manufacturers, and 11,000,000 by inland, coasting, and trans-Pacific steamers. The Canadian Pacific Railway operates a fleet of fourteen steamers on Puget Sound; eight of these are now equipped for the use of oil. Two of them have just been put in commission. The majority of the trans-Pacific steamers navigating to Puget Sound are coal burners and usually secure their coal from British Columbia with small amounts from Washington mines. Some of the Japanese steamers—Mr. Bain made a slight mistake there, I think—are using oil on their westward sailings. For the eastern sailings to Honolulu they fire with Japanese coal; from Honolulu they burn oil and coal part of the way, and then finally oil.

Mr. Norris has referred to the coal mines in Monterey County. I may remark that here we have the only development of a bed of bituminous coal south of the State of Washington. The coal, though a true bituminous, is non-coking.

(*Victoria Meeting, September 18th*, 1912.)

MR. D. B. DOWLING: It is scarcely necessary to remark that the trade of the Pacific slope is still in its infancy, and it is difficult to estimate the direction in which it is likely to develop. Although, as Mr. Bain has suggested, the regular liners will in future doubtless burn oil as fuel, the majority of the freight-carrying steamers will probably continue to consume coal, for the reason that oil is not readily obtainable at ports other than those on this coast.

Mr. H. Mortimer-Lamb: It is possible to conceive of great industrial developments in Western Canada in the next few years. Mr. Bain's paper may well be read in conjunction with the paper contributed to the Transactions this year by Mr. Allan Greenwell, in which the latter shows that manufacturing is invariably attracted to centres of fuel supply rather than coal to manufacturing. The opening of the Panama Canal will undoubtedly affect the industrial conditions of the world. It will open new trade routes, and, perhaps, divert trade into altogether new channels. Mr. Bain has dwelt more particularly on the question of a probable increased demand for fuel for navigation purposes; but the chief hope for Western Canada is the utilization of her immense coal resources in establishing manufacturing industries, and in bringing in raw material from outside to be manufactured in this country. Of course, before this is accomplished, many difficulties necessarily must be surmounted. The high cost of labour as at present obtaining would, for example, be a very serious handicap; but, it must be remembered, that existing conditions in this respect in the West are abnormal, and their adjustment is merely a matter of time. Competition, however, is to be feared both from California, where, as Mr. Bain has pointed out, they have the advantage in oil of a cheap and easily handled fuel; and, perhaps, at a more distant date, from China. China, according to figures recently published, possesses coal resources at least equal in quantity to those of the United States, while the quality, generally speaking, is said to average higher. China is awakening; her people are adaptable, if conservative. They are more conscientious and painstaking, and generally more efficient than the Japanese. When, therefore, they shall have adopted Western methods of business to the exploitation of their great natural resources, Chinese competition will become a factor with which other nations now largely in control of the world's commerce will be obliged to reckon.

Mr. J. J. Shallcross (President Board of Trade, Victoria): Perhaps I may be allowed to remark briefly on the probable effect of the opening of the Panama Canal on freight rates on this coast. The present distance by sea routes to Europe is about fifteen thousand miles. With the opening of the Canal the dis-

tance will be reduced to about seven thousand miles. This must necessarily have its effect in the saving of time alone, for whereas, by the Suez route, it requires ninety days to draw supplies from Europe, the time occupied by way of Panama will be about forty days. More important, however, is the probable effect on transportation between the Pacific and Atlantic coasts. The average rate on freight is now 90 cents per 100 pounds. This will be cut in two. Immigration from Europe to Western Canada will also be affected. At present the cost of the journey, via Montreal, is very high. The journey by way of Panama will not only be much less costly, but more convenient. This, then, should influence greatly the movement of Europeans to the Western coast of this continent.

I should like, however, to also refer to the importance of proving the existence of oil in quantity in British Columbia and in Alberta. Last year the production of oil in California was seventy-five million barrels, or the equivalent of twenty-five million tons of coal. The total production of coal in British Columbia is from three to four million tons per annum; while that of Alberta is about three million tons. The cost of coal to the manufacturer is from four to six dollars per ton; the cost of oil is one dollar a barrel. Oil, therefore, is a far cheaper fuel than coal. There are, it is believed, extensive oil fields in Alaska, and, consequently, in the development of manufacturing on this coast, the Pacific Provinces of Canada will be placed at a disadvantage; for, although we may assemble raw materials as cheaply, that will not offset the advantage possessed by California and Alaska in the matter of a cheaper fuel supply. In view, therefore, of the industrial importance to a country of possessing oil resources, it appears to me that its discovery should not be left to private enterprise, but should be undertaken by the Government.

MR. H. MORTIMER-LAMB: I think the point is well taken. It would unquestionably be of great benefit if we could develop an oil industry in the West; but Mr. Shallcross has possibly exaggerated the relative cheapness of oil as compared with coal for manufacturing purposes. We do not know at present whether we have oil in quantity in this country; but we do know that we

have a practically inexhaustible supply of coal. It has been demonstrated, I believe, that power can be generated from lignite in a gas producer sufficiently cheaply to compete on even terms with power produced from the burning of oil.

Mr. D. B. Dowling: Experiments have been conducted by the Mines Branch of the Department of Mines at Ottawa with a view to determining the most economical production of power from low grade coal. In these experiments, tests have been made with both lignite and peat. It has been found that the cheapest production of power is obtainable from peat and lignite in the gas producer with gas engines. The coal consumption has been reduced one-half and sometimes one-third. Of late, great advances have been made in reducing the cost of power in the steam engine. It may, however, be stated that the cheapest power, probably cheaper than that obtained from the use of oil fuel, is afforded by the gas producer using low grade coals.

Mr. L. O. Armstrong: In one respect I am in disagreement with Mr. Shallcross. He expressed the opinion that the opening of the Panama Canal would result in emigrants selecting that route in preference to making the rail journey across the continent. Time is worth money. The journey from Europe, via Panama, to Victoria, will occupy thirty days, whereas by travelling direct, via Montreal, only fourteen days is required. At present it is not even profitable to transport labourers from Europe by slow steamer.

Mr. H. Mortimer-Lamb: Has manufacturing been established in California as a result of the development of the oil industry?

Mr. Shallcross: I understand that important industries have been established in Los Angeles. You also made some reference to the employment of gas for power purposes. I believe the price of gas is about five cents per thousand feet.

Mr. Armstrong: At ten cents a thousand feet on Lake Huron it is cheaper than coal at two dollars and forty cents.

Mr. Thos. Graham: Mr. Shallcross has rather exaggerated the cost of coal in the West. Probably forty per cent. of our production is small coal, which can be used for steam purposes, and is obtainable at as low a price as one dollar and fifty cents per

ton. The average price obtained for the entire product is less than three dollars and a half a ton.

MR. W. J. SUTTON: In this discussion no reference has yet been made to water powers of the Province. In the preface to his universal history, Prof. Bryce points out that in the future the water powers of the world will have a most important bearing on industrial problems and conditions, and he makes a special reference to the water powers of British Columbia. In this connection, and as an instance, I may mention that until the present ten per cent. of the coal raised at our Cumberland mines on Vancouver Island had been consumed at the works to provide power. In future, this consumption will be conserved by utilizing a water power in the vicinity.

MR. MORTIMER-LAMB: A few years ago we exported to Puget Sound ports, seventy-five per cent. of the coal mined on Vancouver Island. Now we are utilizing for home consumption fully eighty per cent. of our production, which has increased rather than declined. That scarcely indicates that the local coal industry has suffered very severely from California oil competition.

MR. T. GRAHAM: That is true in a sense; but we have lost our foreign market. Moreover, fuel oil, which is sold in competition with British Columbia coal, is admitted into the Province duty free, whereas under the tariff requirements it should be subject to a duty, since its flash test is above the standard specified for free entry.

MR. E. JACOBS: May I suggest that Mr. Chas. Camsell give us some information concerning the oil occurrences in the Mackenzie Basin in Northern Canada?

MR. CHAS. CAMSELL: The oil-bearing rocks, or rather those exposed in the Mackenzie Basin, cover an area of more than three hundred thousand square miles. In the lower part of the Basin where the rocks are exposed oil comes to the surface at a number of places, notably on the north shore of the Great Slave Lake, and again down the Mackenzie valley in the neighbourhood of the Arctic Circle. In this latter locality the employees of the Hudson Bay Company have for many years past obtained tar

for their own use. In the delta of the Mackenzie River oil-bearing rocks are exposed from which bituminous matter exudes.

MR. MORTIMER-LAMB: Has any part of this area been acquired by capitalists?

MR. CAMSELL: No, but some fifteen years ago boring was undertaken, and natural gas encountered.

THE GEOLOGY OF THE NANAIMO COAL DISTRICT.*

By Charles H. Clapp, Ottawa, Ont.

(*Annual Meeting, Toronto,* 1912.)

The Nanaimo coal district, situated on the east coast of Vancouver Island, is underlain by a series of coal-bearing sedimentary rocks, of Upper Cretaceous age, called the Nanaimo series, in three seams, the Wellington, the Newcastle and the volcanics and intrusive granitic rocks. They are themselves moderately disturbed, having in general a simple monoclinal structure with a northwest-southeast strike and a dip to the northeast. The coal occurs chiefly in the lower part of the series, in three seams, the Wellington, the Newcastle, and the Douglas, and has been the source of a flourishing industry for over fifty years. The present coal production is over 1,000,000 tons per year, and the importance of the Nanaimo district in the coal industry may be more easily comprehended when it is realized that it produces over one-third of the entire coal output of British Columbia.

The coal district was geologically surveyed, under the direction of the writer, for the Geological Survey of Canada, during the past field season, the topographic map prepared in 1910 by Mr. R. H. Chapman being used as a field map. With one exception the operating coal companies gave hearty co-operation and Mr. W. J. Sutton, geologist for the Canadian Collieries Company, should receive especial acknowledgement.

The area known to be underlain by productive coal seams embraces about 65 square miles, being but a small part of the basin underlain by sedimentary rocks, which has been called the Nanaimo basin. This basin is one of a series of sedimentary rock basins that fringe the east coast of Vancouver Island. Their rocks are less resistant than the metamorphic and granitic rocks

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which form the axis of the island, and, consequently, have been worn down to a lowland which is surmounted by the Vancouver range composed of the metamorphic and granitic rocks. Since the sedimentary rocks are of varying resistance, as well as moderately disturbed, the coast lowlands are not level, but have considerable relief, extensive valleys having been developed in belts of soft rock, between ridges composed of more resistant beds. It appears as if the eastern part of the Nanaimo basin, which is one of the southern basins, and situated almost due west of the city of Vancouver, had been depressed below sea-level and the valleys drowned, thus forming the long, but often wide channels, passes, and harbours characterisic of this region. The hard rock ridges remain above sea-level as long points and islands, which are characteristically long and occur in chains. On Vancouver Island the Nanaimo basin is about 30 miles long, its greatest inland extent being about 10 miles. It extends much farther to the east and southeast, its hard rock ridges composing the islands of the sound region between Vancouver Island and the mainland of the State of Washington. Its greatest length and width in Canadian territory are 55 and 15 miles respectively. Its total area is therefore about 600 square miles; but, as stated above, the productive portion is only about 65 square miles, and is situated at the northwestern end of the basin, in the vicinity of Nanaimo.

Two conclusions of special geological interest were reached during the survey. The first is that the coal measures were deposited upon an uneven erosion surface of considerable relief, thus localizing the conditions of deposition. The second conclusion is that the measures and coal seams were involved in more or less movement when at least some of the sediments and the clean coal were fairly plastic. As a result the coal seams are extremely variable in thickness and quality so that the mining of the coal is attended with considerable difficulty.

General Geology.—In the vicinity of Nanaimo the rocks upon which the coal measures rest unconformably are chiefly memtamorphic volcanic rocks of medium basicity, andesites, of both flow and fragmental types, the flow types predominating. They are lower Mesozoic—Triassic and Jurassic—in age and be-

long to the Vancouver group, the rocks of which compose the larger part of Vancouver Island. The volcanic rocks are greatly deformed and metamorphosed and were intruded, probably in late Jurassic time, by basic granitic rocks, chiefly granodiorite, concomitantly with the intrusion of the tremendously large Coast range batholith. The granitic rocks were subsequently exposed, since boulders and pebbles of them occur in the sediment of the Nanaimo series. However, they were apparently not worn down to a lowland, because the surface upon which the sediments of the Nanaimo series were deposited is seen to be one of considerable relief, with elevations up to 1,000 or 2,000 feet, and probably more. Small irregularities are directly observable in exposed unconformities; and the contacts of the Nanaimo series with the underlying rocks, where not disturbed by intense folding and faulting, follow very closely the contours of present elevations, which must have been elevations at the time of deposition also, unless far more irregular and complex folding than is elsewhere observed is supposed. One of the best examples of such a contact occurs in the southern part of the Nanaimo basin, west of the town of Crofton. (See Fig. 1.)

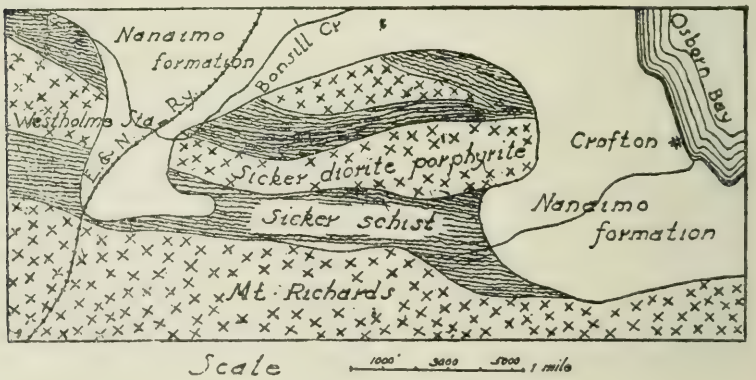

Fig. 1
Contact of Nanaimo series with underlying crystallines, west of Crofton. Contact map by J. A. Allan. Geology by Sicker series diagrammatic.

It appears that the sediments were deposited in bays in the softer rocks (shown diagrammatically in Fig. 1), while the harder rocks evidently formed headlands, since they project into the

Plate I.—Nanaimo river and Mt. Benson, showing lowland underlain by Nanaimo series in the middle ground.

Plate II.—Unconformity of the Nanaimo series and underlying Vancouver volcanics, on the southwest shore of the Strait of Georgia, north of Nanaimo, showing small irregularities of the old conformable surface.

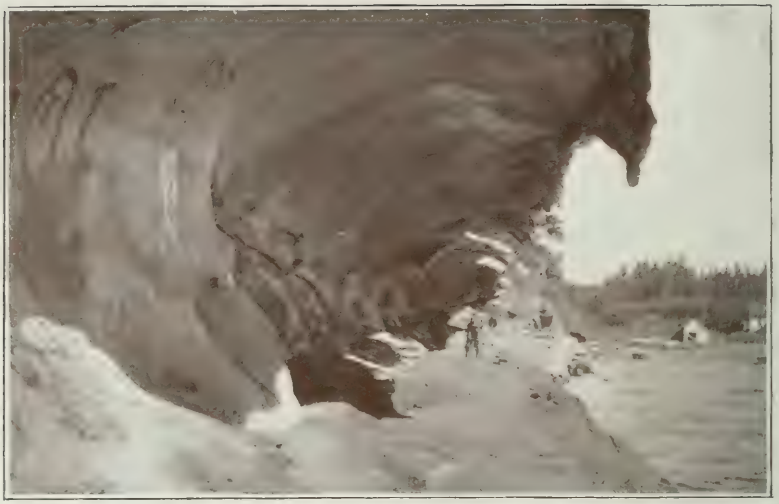

Plate III.—Malaspina gallery, showing the effect of wind and wave erosion on a sandstone of the Nanaimo series, its current having been loosened by the solvent action of the salt-water spray.

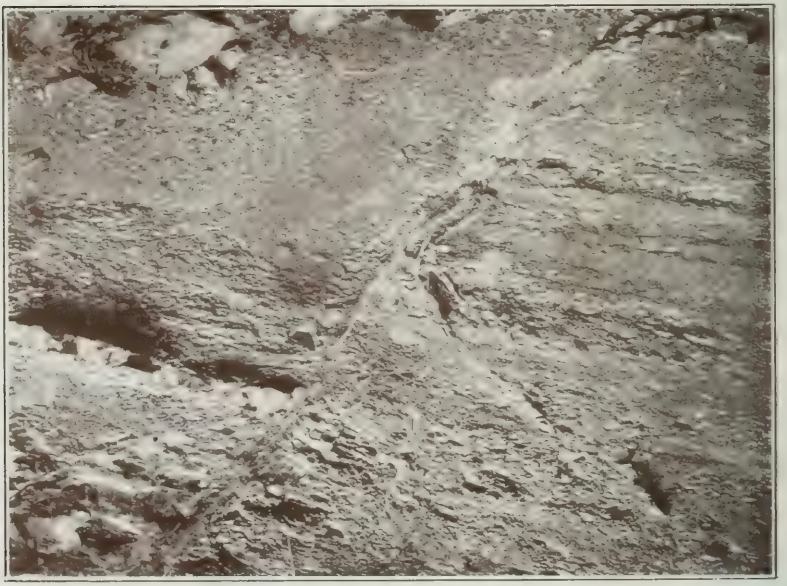

Plate IV.—Cedar District shales, in Nanaimo river, showing fault and small sandstone dike. (Dike extends from the center of the plate to the upper left-hand corner.)

Plate V.- Dike in Cedar district (holes) shore of Trincomali channel. (Hammer rests on the dike.)

rock basins to-day, surmounting them very steeply, in some instances by nearly 3,000 feet. Considering the basin from a still broader point of view it is found that the basal sediments near the larger of the old headlands correspond with formations considerably above the base of the deeper parts of the basin. From all of this evidence, therefore, one feels confident in stating that the surface upon which the Nanaimo series began to deposit was one of great variety and relief.

The Nanaimo series, as shown by its fauna, is partly of marine origin, probably estuarine, since it was deposited on a surface of considerable relief, and under varying conditions, shown by the rapid lateral and vertical gradation of the sediments. The series also contains land plants and coal, most probably of fresh water accumulation. Hence conditions of fresh or at least brackish water, that is, terrestrial conditions, alternated with marine conditions. The upper part of the Nanaimo series, however, contains few or no marine organisms, the only fossils being a few obscure plants. Therefore, it is possible that the alternating conditions recorded in the lower part of the Nanaimo formation were finally replaced entirely by terrestrial conditions. The lithological character of the sediments, the sandstone being composed of angular to sub-angular fragments and of a large percentage of easily decomposed minerals, such as feldspar, indicates a very rapid accumulation and deposition in relatively small basins, where the detritus was not subject to severe wave action. The sedimentation began in upper Cretaceous time, at a stage corresponding with the Chico, or the Pierre, and it looks as if the sediments were first deposited in a marine basin, between the mainland and Vancouver Island, which basin was probably one of deformation, depressed at least as early as the upper Jurassic folding. During the deposition, the sedimentation transgressed inland, at first filling up the irregularities of the pre-upper Cretaceous erosion surface, and then possibly covering even the higher residual elevations. The total thickness of the Nanaimo series was near 10,000 feet toward the close of its deposition, at which time it extended far inland over the denuded crystalline rocks, covering the greater part of the island or perhaps restricted to large depressions.

The conditions of deposition in the northwestern part of the Nanaimo basin, where the coal deposits occur, appear to have been more uniform than those which existed elsewhere, for here the series may be subdivided solely on a lithological basis into various formations, each with its more or less peculiar characteristics. The formations are enumerated and their thickness and general lithological character given in the following table:

	Thickness.		
	Min.	Max.	Ave.
Gabriola formation—Chiefly sandstones	1400	1400	1400
Northumberland formation — Conglomerates, sandstones, and shales	1100	1200	1150
De Courcy formation—Chiefly sandstones....	800	1400	850
Cedar district formation—Chiefly shales.	700	1000	750
Protection formation—Chiefly sandstones.....	600	750	650
Newcastle formation — Fine conglomerates (Douglas coal seam) and sandy shales (Newcastle coal seam) and contains Douglas seam.	150	400	200
Cranberry formation—Flaggy and shaly sandstones, and sandy shales, gritty sandstones and fine conglomerates.....	150	500	250
Extension formation—Chiefly conglomerates, also shales, and sandstone horizons and small coal seams.	700	1500	800
(Wellington coal seam.)			
East Wellington formation—Sandstone.....	25	50	35
Haslam formation (Marine shales)—Chiefly shales	500	800	600
(Departure Bay calcarenites.)			
Benson formation—Basal conglomerate.....	0	400	100
Totals	6,125	9,400	6,785

In general the conglomerates are composed chiefly of quartz and quartzose rocks, the sandstones chiefly of granitic detritus, quartz and feldspar, and the shales chiefly of volcanic detritus, being grayish-brown in colour. From the mere statement of these facts, which constitute a rather peculiar feature of the lithology, a simple, yet fairly plausible, explanation suggests itself. Of all the underlying rocks whose detritus composes the sediments, the volcanic rocks alone were chemically disintegrated and their detritus being very fine grained was deposited as mud which now forms the shales. The granitic rocks were mechanically disintegrated and broke down into a coarse feldspathic sand, furnishing the material for the sandstones. But the quartz

veins and the quartzose rocks were broken down only into a coarse rubble, the material for the conglomerates.

A peculiar feature of the shale horizons of the upper part of the Nanaimo series, especially of those characterized by a large number of small sandstone interbeds, is the occurrence of numerous sandstone dikes. These cut the shales at all angles to the bedding. They are fairly regular, although branching and offset by faults, and the larger, 3 to 4 feet thick, may be traced for at least 100 feet. Although they cut the shales sharply, apparently along joint planes, the shales are frequently bent or slightly contorted next to the dikes. On the shores, where the dikes are best exposed, on account of their greater resistance to wave erosion they stand above the shales, forming low walls, the highest wall noted being three feet. These walls project into the water for some distance and there is an instance of one being utilized as a pier for a small boat.

As a rule the dikes are finer grained than the sandstone interbeds and the cementing material is more calcareous, but in general both are of similar material. Indeed, in many instances dikes protrude from the sandstone interbeds and there are off-shoots from the dikes conformable with the bedding of the shales, giving the appearance of sandstone interbeds, but commonly occurring, however, on one side of the dike only. There are also other smaller and more irregular off-shoots into the shales resembling small apophyses from an igneous dike.

From their occurrence and from their close resemblance to intrusive dikes in California, which have been fully described by Diller* and Newson,** the origin of the dikes is in little question. They appear to have been formed by the injection of soft sands which were forced usually upward along joint planes in the shale, the injection being similar to that of an igneous dike. After the injection the sands were firmly cemented by calcium carbonate precipitated from water circulating through the relatively coarse-grained dike. For our present purposes the most important conclusion to be drawn from their occurrence is that

* J. S. Diller, Sandstone dikes. Bull. Geol. Soc. Am. Vol. I., 1890, pp. 411-442.

** J. F. Newson, Clastic dikes. Bull. Geol. Soc. Am. Vol. XIV., 1903, pp. 227-263.

movement must have taken place while the upper sandstones of the Nanaimo series at least were in a soft and plastic condition. This conclusion is corroborated by other evidence, to be given in the next paragraph, and is a leading factor in determining the great variation of the coal seams.

Another feature also indicates that movement took place while the sediments of the upper part of the series were in a plastic condition. Even in the coarser, more massive beds, such as thick bedded conglomerates, sudden folds or sharp rolls occur, although the beds may be otherwise only moderately disturbed. These rolls which are really more of the nature of small displacements or faults, are so pronounced, that a bed which has a moderate dip in one direction may turn down at right angles so that the dip of the down-turned portion is vertical and its strike is at right angles to the strike of the bed as a whole. The largest of these sharp rolls, exposed on the west shore near the northern end of Newcastle Island, occurs in a coarse-grained, thick-bedded conglomerate, and the width of the down-turned portion is about 150 feet. In spite of the magnitude and abruptness of the displacement, there is not the silghtest indication of extra jointing, shearing, or slickensiding. Instead, the fold has occurred as if the conglomerate was as plastic as wet clay. Hence unless we hypothecate more intense folding than is observed and a much thicker cover, which would induce greater pressure, this type of fold can be explained only by the supposition that the conglomerates and other sediments which have suffered in the same way were soft and plastic when the folding took place.

The Nanaimo series was subjected to great orogenic movements also, which cannot be dated very definitely, but which probably took place during the general and wide spread Laramide revolution. The series was deformed into broad open folds in the northeastern part of the basin, but into closed, over-turned folds broken by reversed and over-thrust faults in the southern part. The axes of folding correspond in general with the trend of the island, i.e., northwest-southeast, although in detail with the outline of the basin. Since the prevailing dip is northeast and the closed folds and fault planes dip to the northeast also, i.e., they have been overturned to the southwest, the forces caus-

ing the deformation must have acted from the northeast, probably having their origin below the basin between Vancouver Island and the mainland.

In the Nanaimo coal field there are several folds of an open character. The largest and closest folds occur along the southwest boundary of the coal field. Here there are also two large reversed faults with a maximum throw of 300 and 100 feet respectively.

During the time between the deformation and the glacial period, the Nanaimo basin, as has been already described, was worn down to a lowland and the eastern part was partially drowned. The region was glaciated in Glacial time and above elevations of 400 feet there is a large amount of glacial till. Below that elevation are found deposits of stratified sand and gravel derived from glacial till, probably of delta and estuarine origin, showing that the land apparently stood some 400 feet lower than at present. This deposition must have occurred during the recession of the glaciers, since the deposits contain ice block or kettle holes, and numerous large erratic boulders. A recent uplift has brought the land into its present position and initiated the present erosion cycle during which the revived streams have terraced the superficial deposits and have cut narrow canyons in the indurated rocks.

Geology of the Coal Deposits.—We can now proceed directly to the special geology of the coal deposits. There are at present three productive coal seams in the Nanaimo district, the Wellington, the Newcastle, sometimes called the Lower Douglas, and the Douglas. The lowest seam, the Wellington, occurs about 700 feet above the base of the Nanaimo series, overlying 600 feet of sandy shale of marine origin, the Haslam formation. The Newcastle and Douglas seams, which are only from 25 to 100 feet apart, the Newcastle being the lower, overlie the Wellington seam by about 1,000 feet, separated from it chiefly by a thick bedded conglomerate, the Extension formation. A fourth and small seam, called the Little Wellington, locally overlies the Wellington at a distance of 20 to 50 feet. It also has been mined in a small way. The Wellington seam has been mined at Wellington, Northfield, East Wellington, Harewood Plains,

and Extension, and is, at present, mined by the Vancouver-Nanaimo Coal Mining Company at East Wellington, and by the Canadian Collieries (Dunsmuir) Company near Extension. The Newcastle and Douglas seams are usually worked together and have been mined extensively in the vicinity of Nanaimo. The mines here are operated by the Western Fuel Company. There has also been a large production from the Douglas seam south of Nanaimo, notably at Chase River, Southfield, and South Wellington. In these localities the Newcastle seam, although readily located, is of doubtful value. There is but one mine producing at present in this district, namely, the South Wellington mine operated by the Pacific Coast Coal Mines.

The coals of the various seams are, as a whole, much alike and furnish a bituminous coal of fair grade. The amount of fixed carbon in the best quality ranges from 45 to 60 per cent. and the ash from 5 to 10 per cent. The following proximate and ultimate analyses are new, being made from samples collected by the writer and analysed by Mr. F. G. Wait of the Department of Mines.

ANALYSES.

Proximate— Analysis by fast coking.	1	2	3
Water	1.65	1.16	1.54
Vol. Combust.	43.25	40.47	33.30
Fixed Carbon	45.52	50.04	56.23
Ash	9.24	7.80	8.44
Sulphur	1.24	0.53	0.49
	100.00	100.00	100.00
Coke	55.38	58.11	64.91
Its character	firm coherent	firm coherent	firm coherent
Fuel ratio	1.07	1.23	1.65
Split volatile ratio	2.92	3.29	4.00
Ultimate— Analysis.	1	2	3
Carbon	72.80	75.53	74.46
Hydrogen	5.17	5.13	5.42
Nitrogen	0.88	1.19	1.37
Oxygen	10.67	9.82	9.82
Sulphur	1.24	0.53	0.49
Ash	9.24	7.80	8.44
	100.00	100.00	100.00

No. 1. Coal from the Wellington seam.
No. 2. Coal from the Wellington seam.
No. 3. Coal from the Douglas seam.

The most striking feature of the seams is their great variability in thickness and quality. The thickness varies from almost nothing to over thirty feet, sometimes within a lateral distance of less than 100 feet. This variation is caused by irregularities in either the roof or floor, and occasionally in both. In quality the seams vary from where they are entirely composed of clean, bright coal with about 5 per cent. ash to where they are entirely composed of a dirty slickensided coal locally called "rash," with over 50 per cent. ash. The following is a proximate analysis of the rash from the Wellington seam.

Proximate analysis by fast coking: "Rash."

Water	1.59
Vol. Combust.	24.15
Fixed Carbon	19.29
Ash	54.97
Sulphur	undet.
	100.00

This variation may be more fully appreciated if taken up in more detail. The Wellington seam rests on a firm sandstone floor, which is fairly regular although a few sharp rolls do occur in it. The roof, however, varies greatly in character from sandy shale to conglomerate, with many irregularities, especially when it is sandy shale. The average thickness of the seam is from 4 to 7 feet, but it occasionally pinches to virtually nothing and then suddenly thickens to 10 or 12 feet. The floor may be nearly smooth, but the roof in passing from the thin to thick portion of the seam rolls sharply, and often irregularly, upward. In some instances the roof is even overturned forming an overlap in the seam of several feet, at least 25 feet in one instance. These sharp rolls are locally called "faults." Invariably at the thin places, or "pinches," the coal is dirty and slickensided, while in the thick places, or "swells," it is clean, black in color with a sub-brillant lustre, and broken only by a few irregular joints. Rash is usually found near the top and bottom of the swells and rarely in thin partings near the centre. The only parting noted is in a 12-foot swell, about 3 feet above the base, and is

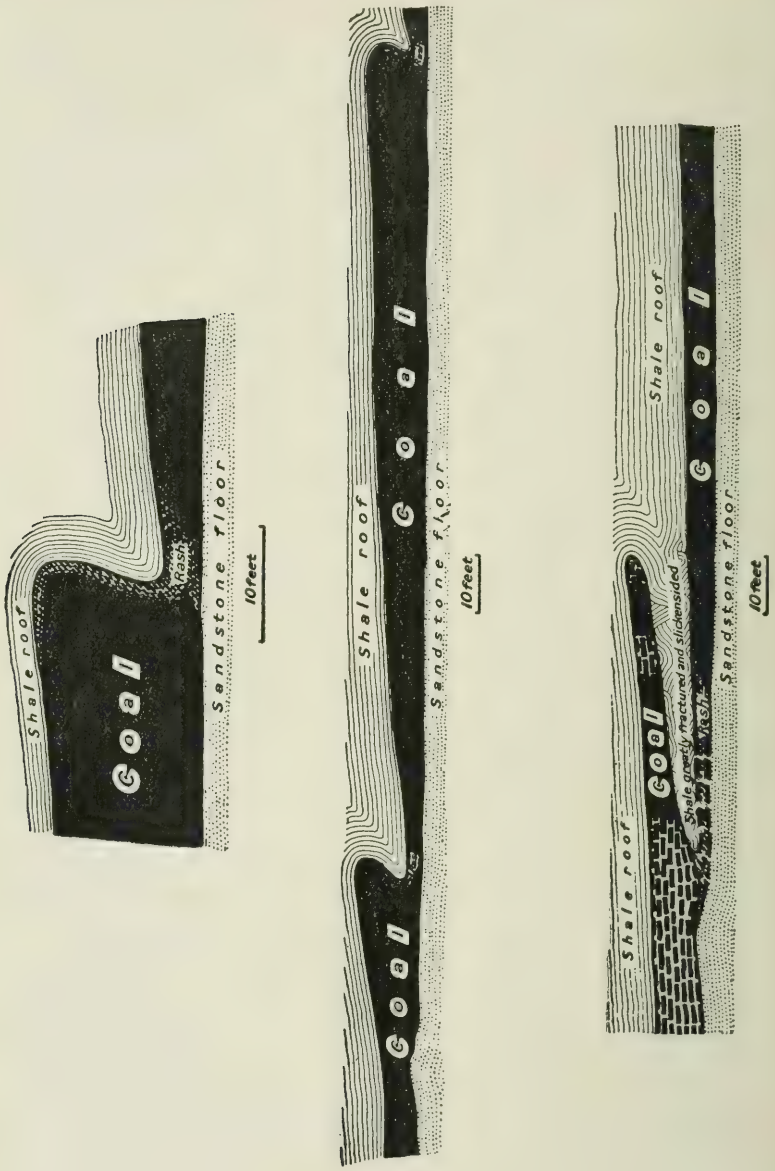

Fig. 2

Sections of the Wellington Seam, showing rolls and overlaps, where the seam is represented as broken its position is inferred.

only about an inch wide and is not regular or persistent. Some bone occurs in the coal, even in the swells, as small lenses seldom more than a quarter of an inch thick. In some instances the coal is clean and unfractured against the upturned roof, but more commonly it is somewhat slickensided and even contorted. The roof at the rolls is always contorted and slickensided.

The strike of the rolls corresponds with the strike of the measures, that is northwest to west, and the pinches occur in the southeast or south side of the rolls with the corresponding swells on the opposite side. Where the seam is overlapped, the overlap is to the southwest or south.

These features are illustrated by the following sections, which are drawn to scale. (Fig. 2.)

It appears from the evidence given above as if the variation was due in large part to a folding which affected the coal seams when the clean coal was in a fairly plastic condition. This conclusion is especially well substantiated in another part of the Wellington seam, where it is composed of several sub-seams separated by dirty slickensided coal or rash. During the deposition of the seam, conditions in which fairly clean carbonaceous matter was deposited must have alternated with those during which the carbonaceous matter was deposited with a large amount of silt. This is shown by a type section of the seam, taken where it is fairly regular and not much disturbed. (Fig. 3.)

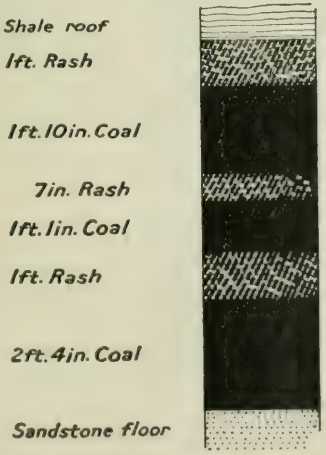

Fig. 3.

Section of Wellington Seam, where relatively undisturbed and regular.

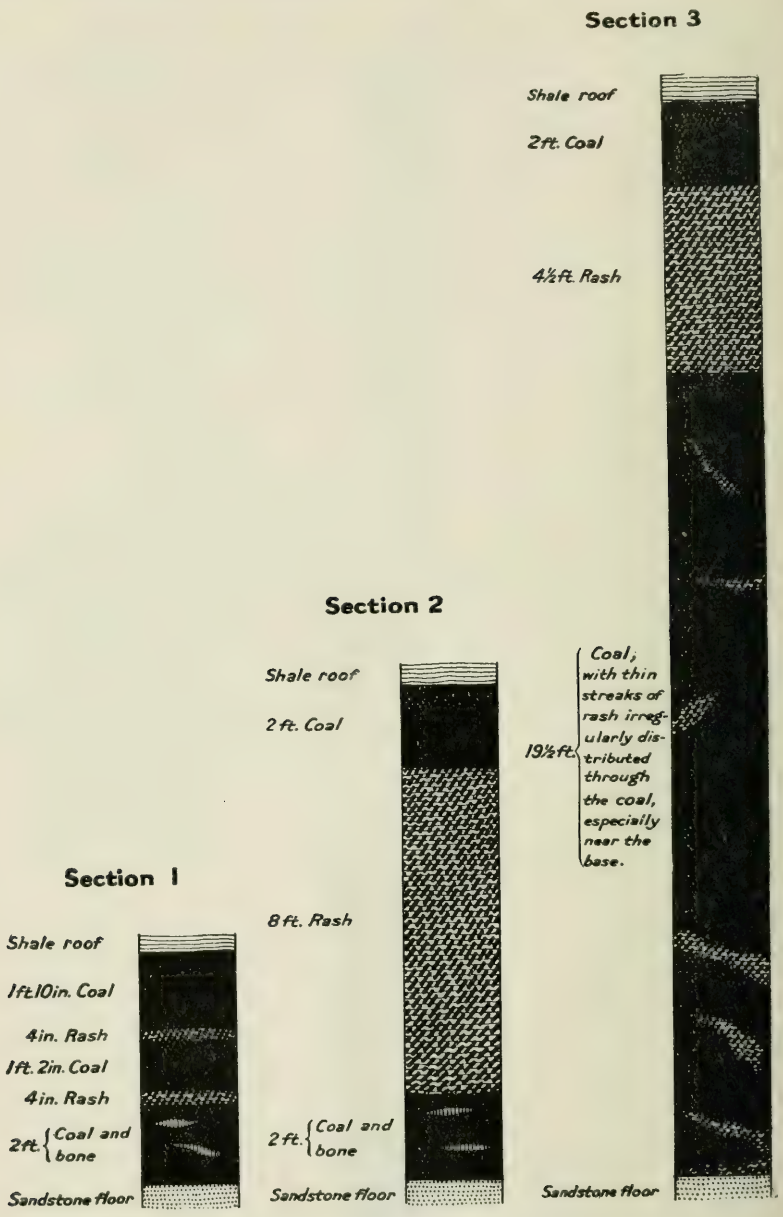

Fig. 4.

Sections of Wellington Seam, showing them in thickness and quality.

When the seam was folded the clean coal was apparently forced away from the tight bends where the folding caused an increase in the vertical pressure, and left the seam at these places composed almost entirely of rash. The clean coal flowed to where there was a corresponding relief of vertical pressure forming a swell, where the seam consists except for the rash at the top and bottom of the seam chiefly of clean bright coal. This feature is shown by the following sections of the seam. (Fig. 4.)

Besides the barren places or wants due to folding subsequent to the deposition of the seam there are large wants due solely to silting, for in some cases the silting must have persisted throughout the period of coal formation. Also large and persistent partings of shale occur between the sub-seams, as is shown by the following section. (Fig. 5.)

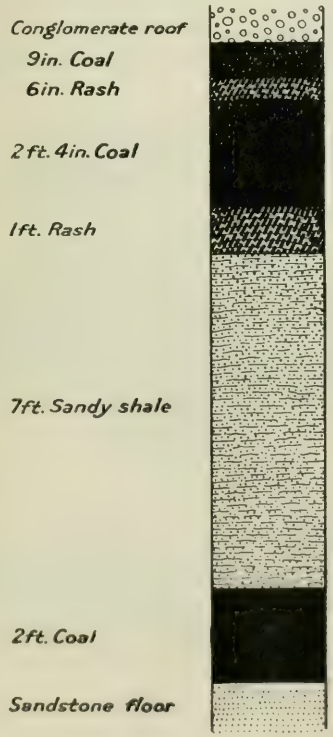

Fig. 5.

Section of Wellington Seam, showing thick shale parting.

Both types of variation occur in the Douglas seam, there being large wants due to silting (see figure 6) and pinches of

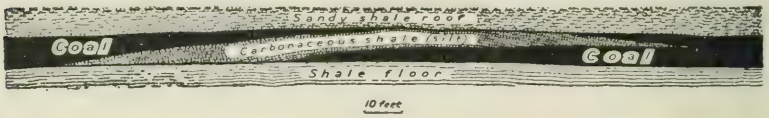

Fig. 6.
Section of Douglas Seam, showing parting of Carbonaceous shale "a want due to silting."

dirty coal and swells of clean coal. The seam varies from nothing to 30 feet in thickness and averages about 5 feet, although over large areas the average thickness of the mineable coal is between 3 and 4 feet. The floor of the Douglas seam is usually a rather weak sandy shale, and the roof, although stronger, is very variable, ranging from a sandy shale to a fine grained conglomerate, the principal type being a shaly sandstone with sandstone layers and lenses of fine grained conglomerate. Unlike the conditions in the Wellington seam the pinches and swells are caused chiefly by irregularities in the floor, the roof being fairly

Fig. 7.
Sections of Douglas Seam, showing rolls.

smooth (see figure 7). At the pinches the seam is composed almost entirely of rash like that of the Wellington seam, although as a rule it is harder. The coal occurring in the swell has a compact texture, but rather dull lustre. It is irregularly broken into large irregularly shaped blocks. Near the pinches some of the coal is slickensided and contorted, but where these features are shown the coal contains a higher percentage of ash. The coal seam is displaced also by small faults, although an actual break seldom occurs, the coal having been forced along the plane or zone of dislocation (see figure 8). Rarely the entire seam folds or wrinkles without any appreciable variation in thickness (see figure 9).

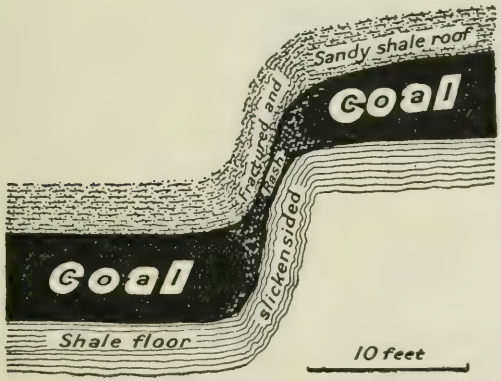

Fig. 8.
Dislocation or fault in the Douglas Seam.

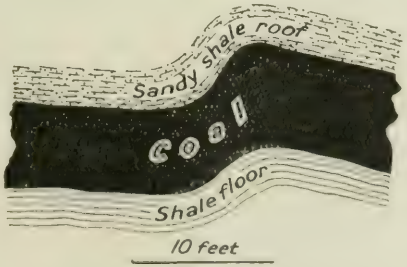

Fig. 9.
Small fold or wrinkle in the Douglas Seam.

Where rolls, pinches, and faults occur at comparatively shallow depths, their presence is usually indicated on the surface by a small questa-like ridge, with a steep obsequent slope and a gentle back slope corresponding with the bedding.

The Newcastle seam is more regular than the Wellington or Douglas seam, but is thinner, varying, as far as known, from 20 to 45 inches where mined, and contains more numerous and more regular partings. It is also less extensive in area than the other two seams.

Similar minor disturbances or local variations or interruptions of coal seams are rather common and have been described by various writers.* However, they appear to have been formed in several different ways. Some are due to irregularities in deposition, others to contemporaneous or later erosion, but probably the greater number are formed by some kind of deformation.

Summarizing our knowledge of the conditions existing in the Nanaimo field in so far as they throw light on the origin of the minor disturbances or local variations, we have the following points:

1. The conditions of deposition were local producing rapid variation in both vertical and lateral directions.

2. The relatively undisturbed coal seams are dirty, the dirty coal alternating with clean coal, and in places are composed entirely of dirty coal or carbonaceous shale.

3. The presence of intrusive sandstone dikes and of sharp rolls in the upper part of the Nanaimo series indicates that movement has taken place while some of the upper sediments of the series were in a soft and plastic condition.

4. The general deformation of the measures indicates that they were subjected to large orogenic movements, the forces act-

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* The following references give the fullest treatments of the subject.

H. F. Bain—"Origin of Certain Features of Coal Basins:" Journal of Geology, Vol. 3, 1895, pp. 646-654.

A. J. Collin—"The Arkansas Coal Fields:" Bull. 326, U. S. Geol. Survey, 1907, pp. 48-49.

W. S. Gresley—"Clay-veins Vertically Intersecting Coal Measures:" Bull. Geol. Soc. Am., Vol. 9, 1898, pp. 35-58.

C. R. Keyes—"Coal Deposits of Iowa:" Iowa Geol. Survey, Vol. 2, 1894, pp. 49-53; pp. 178-189; p. 229, and p. 249.

B. Willis—"Some Coal Fields of Puget Sound:" 18th Ann. Rept., Part III., 1896-97. U. S. Geol. Survey, pp. 410-412.

W. G. Woolnough—" 'Stone Rolls' in Bulli Coal Seam of New South Wales." Jour. Roy. Soc. N. S. Wales, Vol. 44, 1910, pp. 334-340.

ing from the northeast, after some of the sediments were indurated enough to act as competent members, thus producing large open folds, and in consequence of the folding lateral movements or sliding of one bed upon another must have been produced.

5. The variation in thickness of the seams is due to irregularities in either the roof or the floor, and occasionally in both. The floor of the Wellington seam is smooth, while the roof is deformed, but the roof of the Douglas seam is smooth, while the floor is greatly deformed.

6. The floor of the Wellington seam is a firm and fairly uniform sandstone, while the roof is variable, but is chiefly sandy shale. The floor of the Douglas seam is a weak, sandy shale, while the roof is stronger although variable in character, chiefly a sandy shale with sandstone layers and conglomerate lenses.

7. The deformed roof of the Wellington seam and the deformed floor of the Douglas seam bend sharply, the roof of the Wellington seam being sometimes overturned.

8. The deformed roof or floor is always slickensided and usually contorted.

9. In the pinches the seam is composed chiefly of rash, while in the swells it is composed chiefly, except for the rash at the top and bottom of the seams, of clean unfractured coal, with no definite and persistent partings or cleavage.

10. In some instances the coal is clean and unfractured against the deformed roof or floor, but is usually slickensided and even contorted.

11. The strike of the minor disturbances corresponds with the strike of the measures, and the swells occur in the northeast or north side of the rolls, and the pinches and overlaps are to the southwest or west.

12. Several displacements and folds or wrinkles occur affecting the seams.

The conclusions drawn from these facts as well as from the comparison of the conditions at Nanaimo with those described as occurring in other fields are:

1. That the original seams were dirty and that some of the local variations are due to the lack of deposition of carbonaceous

matter free enough from silt to form coal of sufficient purity to mine.

2. That the minor disturbances of the coal seams were caused by forces acting from the northeast, beginning at a time when the upper members of the Nanaimo series and the coal relatively free from silt were soft or fairly plastic and lasting through the general period of deformation, during which much of the lateral adjustment necessitated by the folding took place by lateral movements and sliding along the coal seams.*

3. That the relative strength of the roof and floor determined in general the relative amount of the deformation in each.

4. That the clean coal was more plastic than the dirty coal or rash and was, therefore, squeezed away from the tight bends where there was an increase of vertical pressure, to the limbs of the rolls where there was a corresponding decrease in vertical pressure.

5. That the later deformations caused the greater part of the slickensiding and contortion of the coal, as well as the slight faulting and wrinkling.

6. Possibly that original or initial irregularities in the seam determined the location of the minor disturbances.

Minor disturbances and local variations or interruptions in coal seams are of great commercial, as well as scientific, interest. As has already been pointed out† "the constantly recurring industrial disputes owe their origin, in no small measure, to the difficulties experienced in framing satisfactory agreements for the "working of deficiency places" where the miner cannot, under ordinary circumstances, make what he considers a fair living wage." And of course they present almost continual, as well as varied, problems to the mine operator who must overcome the difficulties caused by them in the best and cheapest manner.

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* See Bailey Willis—"Some Coal Fields of Puget Sound:" 18th Ann. Rept., Part III., 1897, U. S. Geol. Survey, pp. 408-409.

†W. G. Wollnough—"Stone Rolls" in the Bulli Coal Seam in New South Wales. Journ. Roy. Soc. N. S. Wales, Vol. 44, 1910, p. 334.

DISCUSSION.

MR. W. J. DICK:—The author has developed a number of points of importance to the miner. The first is that the coal beds were laid on a very uneven floor on the volcanics. This is especially marked in the Comox field, which is situated about sixty miles to the north of Nanaimo. At certain places in Number 5 Mine the coal seam rests directly on the volcanics. There is usually a small thickness of measures beneath the coal seam at Comox, while in the Nanaimo district there is a considerable thickness of blue shales between the coal and the volcanics. The next point is that in the different coal seams "wants" were found; also that movement had taken place at the time the coal was deposited. This was shown by the slicken-sided rash and by the silt deposited between the coal in the seams. There has also been movement subsequent to the deposition of coal as shown by a fault extending from old No. 5 mine towards the powder works. The downthrow of this fault is about 160 feet. The Baynes Sound fault in the Comox district has a downthrow of at least 300 feet. In this field, "wants" and good coal are often found very close together. For example, in the Alexandria mine 21 feet of coal is found on the south side, while a short distance away on the north side much thinner coal is found. As a result of these conditions the difficulties of mining are increased, while also it is impracticable to provide for the same schedule of wages (on a tonnage basis) in all parts of the same mine, much less in different mines. If a man happened to be working in a good place with "high coal" he would necessarily earn larger wages; in the case of a man working in a district or place where "wants" were frequently encountered it might be necessary to compute his wages on a yardage, or on a yardage and tonnage basis.

NOTES ON THE PROGRESS OF DEVELOPMENT WORK IN COAL AREAS OF ALBERTA AND SASKATCHEWAN.*

By D. B. Dowling, Ottawa, Ont.

(*Western Branch Meeting, Vancouver, February,* 1912.)

Coal Areas on the Grand Trunk Pacific.

The principal areas reached by the Grand Trunk Pacific Railway are those near the mountains. The first mine to produce coal is situated on the Athabaska River near Fiddle Creek, and operated by the Jasper Park Collieries. The following notes have reference to the principal developments during the summer of 1911, in what are practically new areas:

Jasper Park:—Prospecting, of which note was taken last year was, during the past season, continued with renewed vigour. Little development work was undertaken on the west of Brule Lake, near Folding Mountain, a large party of men was engaged tracing the measures to streams flowing to Solomon Creek; and it is probable that following the completion of the line of the Canadian Northern Railway, the northern extension of the Scovil Creek measures will become productive. South of Brule Lake, near Folding Mountain, a large party of men was engaged in tracing seams, while finds were tested by tunnelling. Seams were found and tested at the headwaters of Moose Creek; but little development work was attempted.

Chief activity was confined to the south side of the river, where at the Jasper Collieries every effort was made to prepare for a preliminary shipment of coal. The first carload was delivered to the railway company in the last week of September. By November 13th the output was 130 tons per day, and by December 16th this was increased to 275 tons. The present surface

*By permission of the Director of the Geological Survey.

plant is merely a temporary installation, since a careful survey is requisite before the location of a permanent tipple and main entry is decided. In the meantime, the temporary works do not interfere with this installation, and the present entry 240 feet above the permanent entry will serve for ventilation and other purposes. The situation at the mine at present is as follows:— The line of the Grand Trunk Pacific, on the south side of the Athabaska, skirts the foot of a gravel-faced terrace rising to a height of about 270 feet above the tracks. There is a gentle rise from the edge of the terrace to the foot of a sandstone ridge, which, rising more rapidly, is south easterly in direction. Along the eastern face a coal seam has been traced. An entry on this coal seam has been effected by a tunnel along its strike from the terrace level. This tunnel has been driven into the hillside for rather over 2,000 feet. Mining above the entry has been inaugurated. The surface is there over 200 feet above the tunnel and a small output from this block of coal was made, as above stated. The cars are loaded in the tunnel at chutes and drawn by horse to the top of the terrace. They are then lowered by cable and hoisting engine, on an outside slope, to a temporary tipple at the siding. An inside slope on the seam is in progress to reach the level of the permanent entry, which will be about 240 feet below the present one, and will enter the hill from a point near the permanent tipple. The seam dips at an angle of about 56 degrees from the horizontal. The system of mining will depend greatly on local conditions. There should be, however, a large supply of coal above this entry. The mining and haulage costs should be low.

Edmonton Coals West of Edmonton:—The coal horizon which underlies the city of Edmonton is being mined only in the outskirts of the town, since the possible damage to property by the sinking of the surface is feared. Attempts are being made to reach the horizon at points at which shipping facilities will be available. The sinking of shafts at Saint Albert on the Canadian Northern Railway about six miles northwest has progressed. The coal will be raised from about 250 feet to the surface. The seam as tested by boring, is reported at seven feet. Farther west the higher layer of coal of the Edmonton forma-

tion outcrops at the surface near Wabamun Lake, and is now mined in the vicinity of the Grand Trunk Pacific Railway. At Gainsford, a shaft had nearly reached a seam which is reported to be ten feet in thickness. Near Pembina River several shafts have been sunk to seams found in the banks of the river, and coal, it is expected, will be mined there shortly. Again westward, the coal horizons appear at the surface in the edge of the disturbed belt of the foothills, and these seams from their thickness and number probably represent the same horizon as that of the upper part of the Edmonton formation. An uplifted block of these rocks is found on the headwaters of the Embarras River, and southeast to the Pembina. On the Embarras headwaters, the Yellowhead Pass Coal and Coke Company are preparing to mine from several seams directly the railway branch from the Grand Trunk Pacific shall have been completed. This line will also pass near mines operated by the Pacific Pass Coal Fields, Limited, whose holdings reach to the Pembina River.

Eastern Outcrop of Edmonton Coal Formation:—The report on the Edmonton coal field (No. 1115) contains notes on localities south and east of Edmonton at which the same coal horizon has been discovered, and in many places mined. These include Tofield, Round Hill, Bawlf, Camrose, Battle River, Red Willow Creek, Paint Earth Creek, and the Knee Hill country west of Red Deer River.

Grand Trunk Railway, east from Edmonton. Tofield:—The exposures of the Edmonton coal measures on the Grand Trunk Pacific extend eastward to past Beaver Lake. In this vicinity coal is being mined and quarried. Just south of the town of Tofield, a flat-lying seam about nine feet in thickness has been found. The cover (from 15 to 20 feet) is mainly sandy shales in which are streaks of hardened sand approaching sandstone. The seam is now being worked by two companies. Steam excavators are being utilized, and the exposed coal quarried and loaded either on to railway cars or waggons. Drilling at the town, which is below the level of the coal seam, has resulted in the discovery of another seam at a horizon approximately 200 feet below the surface seam. This would appear to be the lowest seam in the Edmonton measures. The coals prove on analysis to

be excellent fuels of the sub-bituminous class. The surface seam does not appear to have suffered from the effect of weathering, due to the thin cover, to as great extent as has been reported. Small areas of the exposed coal show the upper surface somewhat decomposed, but the character of the main portion of the bed is represented by the following analysis of sample from nine foot seam, Tofield Coal Co.:

Moisture	15.55
Volatile Hydrocarbons	35.09
Fixed Carbon	44.30
Ash	5.06
	100.00

The sample reported to have been taken from the bore hole at a depth of 200 feet below, is slightly more compact, but, is apparently of much the same grade of fuel as that at the surface. Analysis:

Moisture	11.12
Vol. Hydrocarbon	37.88
Fixed Carbon	42.81
Ash	8.19

Areas on C. P. R. and C. N. R. Branches.

Coal Area West of Brazeau Range:—Notice of the discovery of this area of coal bearing rocks was published in the Summary Report of the Geological Survey for 1909, p. 147. No prospecting had apparently been done toward the discovery of workable seams of coal until the summer of 1911, when a party under the direction of Mr. Norman Fraser, spent a short time in the search therefor. Three seams were uncovered, one of which is of workable thickness, 14 feet of coal being reported. This seam has been traced southward from Mire Creek over a ridge having an elevation of 1,500 feet to near the Saskatchewan and as the dip of the beds is not at a high angle, there will be a large tonnage of coal above the entry level which may be obtained from either the Mire Creek or Saskatchewan valleys. The character of the coal as reported from analyses will be slightly lower in fixed

carbon than that of the Bighorn basin, but it has good coking qualities.

On the main Brazeau River, the continuation of the measures of the Bighorn Basin have been found and several seams opened. The principal seam is reported to have about twenty feet of coal.

Kananaskis River, Bow River, Branch of Lusk Creek:—Development work on the continuation of the measures of the Cascade basin southward on Kananaskis River was not very actively prosecuted in 1911, since a continuance of operations is dependent on the provision of railway facilities. On the head waters of this stream and east of Tombstone mountain, a narrow strip of the coal bearing rocks is found high above the Kananaskis valley. Application has been made for some claims or leases, but access to the area may be difficult.

In the foothills, east of Kananaskis River, the crest of an anticline running northwest from Moose mountain is dissected by streams draining east to Jumping Pound Creek and west to Lusk Creek, a branch of Kananaskis River. At the apex of this anticline some of the valleys cut through the soft beds of the Colorado group of the Cretaceous, and one or two through the Dakota to the heavy conglomerate bed at the top of the Kootanie. The nearest of these exposures to the existing railway lines is on an east branch of Lusk Creek. A prospecting party located a "camp" in this valley, and by means of a hand-operated diamond drill pierced the upper part of the Kootanie. That this method was inadequate is shown by the fact that the drill hole reached a depth of only 175 feet, and went through the upper part of the sandstone. As the hole was near a fault or break which extends along the valley, the water forced downward through the drill did not return; hence small seams of fractured coal may have been pierced in that distance. None of workable thickness was, however, found, but probably better facilities for testing the measures will be provided.

Canadian Pacific Railway Branches.—The various eastern branches from the Calgary and Edmonton line cross the eastern part of the coal field underlain by the Edmonton formation. On

the Wetaskawin branch, coal mines have been opened near Camrose and later another near Bawlf.

The Bawlf Collieries.—These are on Sec. 10, Tp. 46, R. 18, west of 4th Meridian. The coal is under a thick cover of sandstone and should be easily mined on account of the solid nature of the roof. At a depth of 140 feet, a seam of ten feet (10 feet) is found. Beneath this, separated by from 10 to 15 feet of sandstone, lies another seam of 6 feet thick. Shafts and hoisting machinery were completed and the mine opened in 1910.

The extension of the Canadian Pacific Railway branch line from Lacombe has opened for settlement a large area east of Sullivan Lake, and a prosperous town, Castor, is now built at the crossing of Beaverdam Creek. The influx of settlers and the establishment of a town at this point has created a demand for coal and the coal seam that here underlies the town at a depth of only a few feet, is being mined by two companies.

Castor Coal Company.—(Sec. 3, Tp. 38, R. 14, west of 4th Meridian.)—Stripping operations are being conducted at the outcrop of a seam near the railway in "Subdivision 2." The thickness of seam is 6 feet 2 inches and has a parting of 1 inch clay, 29 inches below the top. An analysis (made by F. G. Wait) of a sample taken from the tunnel, 57 feet from the outcrop shows:—

Moisture	25.89
Vol.	34.13
Fixed Carbon	35.21
Ash	4.67
	100.00

The first opening made on this seam was on Subdivision 9. At the eastern part of the mine the coal is 6 feet 6 inches thick, increasing, in the westward part, to 7 feet 6 inches. Here the cover above the coal ranges from 6 to 9 feet. It is proposed to strip the cover over an area of about 30 acres. The coal under this light cover in the upper part of the seam, has slightly deteriorated, but, judging from samples, this is not the case in the lower part of the seam, where, in fact, the coal is of the same grade as that of the tunnel sample. The following analysis

of a sample from the old mine was made by F. G. Wait, of the Mines Branch, Ottawa:

Moisture	24.75
Volatile	33.94
Fixed Carbon	35.31
Ash	4.98
	100.00

On Subdivisions 8 and 9, the maximum cover is 30 feet and the coal seam is from 8 to 9 feet, as reported from borings.

Grading for a railway spur has been completed through the western and northern part of the property and there will be two entries driven, one made north and one south from Subdivision 9 to entry No. 1 on Subdivision 2. The western part of the property will probably be mined by shaft at the railway.

The Battle Axe Mine.—(S.E. ¼, Sec. 26, Tp. 37, R. 14, W. 4th.)—The seam on this area varies in thickness from 6 feet to 4 feet, the cover being considerably less than on the property to the north of the town. It is quite probable that the seam could be more economically stripped than mined.

This coal horizon has been traced in a southerly direction for sixty miles from Castor by settlers, and the reported thickness and cover over the coal at the several localities mentioned, is given below:

At Garden Plains on Sec. 1, Tp. 34, R. 14, W. of 4th Meridian, the seam is 4 feet, the cover ranging from 5 to 10 feet. Coal has also been found on Sec. 8, Tp. 32, R. 13, but the thickness is not known. Colonel Walkers Mine on Berry Creek, or between Berry Creek and Bull Pound Creek, seems to be on the summit of a hill. The coal may thus be restricted to an irregular oval shaped area, but should re-occur to the west. The locality is S.E. ¼, Sec. 19, Tp. 29, R. 12, W. of 4th. The south half of this quarter-section is under lease to W. Oscar. The seam is reported at 11 feet under 8 or 10 feet of cover.

In the same locality, 8 miles south on Sec. 12, Tp. 29, R. 13, W. of 4th, eight feet of coal is reported under light cover and another report is to the effect that the seam has been found midway between the exposures mentioned.

What might be termed a stripping area is thus tolerably well defined along the eastern outcrop of the Edmonton measures extending from Tofield in Tp. 50 to the Berry Creek locality in Tp. 29—a distance of 132 miles, the seam having a maximum thickness of 11 feet and a general average of 8 feet, but in portions as thin as 4 feet. The potential quantity of domestic fuel easily obtained in large measure by stripping is thus seen to be enormous.

Northern Extension of Medicine Hat Area.—On the Red Deer River, the Lethbridge seam was mapped by Dr. G. M. Dawson as outcropping on the banks for many miles below the mouth of Bull Pound Creek. Last year, a mine was opened at Fieldholme on Sections 6 and 7, Tp. 23, R. 14, west of 4th Meridian. The coal seam mined is 5 feet 6 inches thick.

Mannville.—The northern portion of the exposed coal bearing rocks belonging to the Belly River formation, or the continuation of the coal bearing beds of Medicine Hat and Lethbridge is exposed northward to the valley of Vermilion River north of Mannville, Alta., a station on the Canadian Northern Railway. Small seams of coal are reported at several localities. A few inches of coal occurs on Sec. 13, Tp. 52, R. 10, west of 4th Meridian and probably the same seam reappears at Spruce Bridge, a point about two miles upstream.

An occurrence most likely to be a mineable seam is found on the farm of W. H. Warwood on Sec. 16, Tp. 51, R. 9, West of 4th, about 6 miles from Mannville in the valley of the Vermilion River. Coal was cut while sinking a well at a depth of 17 feet. The seam is reported to be 5 feet thick. An abundant flow of water which occurred at a depth of 14 feet from the surface, would render mining difficult, but if the seam were persistent, this difficulty might be overcome. Samples of the coal, representing the excavated material, analysed by Mr. F. G. Wait, yielded:

Moisture	27.47
Volatile Combustible	30.26
Fixed Carbon	28.98
Ash	13.29
	100.00

Brock, Saskatchewan.—Another locality in the northern extension of the Belly River beds at which coal is found, is in the vicinity of Brock, a station on the Calgary-Saskatoon branch of the Canadian Northern Railway, situated about 100 miles southwest of Saskatoon, and the occurrence is the nearest at present known to that town. The discovery was made while drilling a well on Sec. 22, Tp. 28, R. 20, West of 3rd. The character of the country is "rolling," and the well which was sunk on a hill top pierced the coal seam at a depth of 130 feet. To the northwest a dry coulee crosses the section and it is probable that the seam lies beneath the bed of this valley, and could be reached at a much less depth. An open, 6-foot square shaft was dug at the hilltop to the depth of 140 feet and stood untimbered and dry. Last winter several tons of the coal were raised by block and tackle. Information given by Mr. McKay, manager, Northern Crown Bank, is to the effect that the seam is nearly 10 feet thick on one side and will average about 7 feet.

The upper portion of the seam is mainly dust and black dirt. There are, however, two feet of solid coal in the middle. From a sackfull of the extracted coal, samples that would be representative of the mass including also the dirty part, were taken and gave the following analysis:

Moisture	25.70
Volatile	26.95
Fixed Carbon	28.42
Ash	18.93
	100.00

It was quite evident that if samples of the solid coal only had been taken the percentage of ash would be much lower. The locality is in the unforested area and in this field the coal, although of about the same grade as that of Souris, will be valuable for local consumption. The cost of timber for mining purposes will be heavy; but the conditions are such that drainage should not be an important item of expense. The roof, although of clay, is strong. At the time of the writer's visit there was

no water in the untimbered pit; the walls appeared firm, yet precautionary measures should be taken to guard against falls of rock before proceeding further with the development of the mine.

THE YUKON COAL FIELDS.*

By D. D. Cairnes, Ottawa, Ont.

Introduction.

Yukon territory is generally and most widely known as the district in which the world-renowned Klondike placer gold deposits occur; and since 1898, each spring has witnessed an influx to this extreme northwesterly portion of Canada, of prospectors and miners, and their usual followers, the majority of whom "go out" to more southerly localities before the freeze-up, possibly to return the following spring. Placer gold in Yukon is not confined to the Klondike district, however, but has been discovered and is being mined more or less extensively, in a number of other widely-separated localities, in Stewart River and Kluane districts, along tributaries of Sixtymile, Fortymile and Big Salmon rivers, on Nansen creek a tributary of Nisling river, and elsewhere.

Lode mining properties have also been developed, particularly during the last six or seven years, and mainly in the southern portion of the territory, where copper and gold-silver ores have been mined at several points. In other parts of Yukon large deposits of copper, gold, silver, and antimony ores are known to occur, which have been little if at all developed, and are under present conditions, at least, practically inaccessible.

Though Yukon is thus known to be rich in placer and lode mineral deposits, it is not generally realized that mineral fuels have also a wide distribution in the territory. Yukon contains an area of about 196,976 square miles; it is thus considerably larger than Great Britain and Ireland, and almost as large as the German Empire. A great portion of this extensive territory still remains practically unknown even to the prospector and miner; in fact, almost all exploration has been restricted to regions

*By permission of the Director of the Geological Survey, Department of Mines of Canada.

within easy reach of the navigable waterways. A glance at the accompanying map will show how extensive are the coal-bearing formations in the limited areas explored. Should the mineral fuels thus prove to be as correspondingly plentiful in the unprospected and unexplored portions of Yukon as in the better known localities, they will constitute a great future mineral asset to Canada, particularly, since, as has been just mentioned, metalliferous deposits have such a wide distribution in the territory.

In preparing this paper, the writer's chief purpose has been to present a summary of what is known concerning the different coal fields of Yukon, with a view to emphasizing the great possible future economic importance of these deposits. The main features concerning the geology of the coal measures, so far as they are known, are also described in the hope of assisting future explorations in this as yet but slightly explored territory.

COALS AND COAL-BEARING FORMATIONS.

The coals of Yukon range in character from low-grade lignites to fuels decidedly anthracitic in character, and are all either Tertiary or Jura-Cretaceous in age. The Tertiary mineral fuels throughout the territory, are all lignites, and are characterised in most places by containing considerable fossil resin or amber; while those formed during Jura-Cretaceous time, range from high-grade lignites to anthracitic coals.

Tertiary coal-bearing beds do not cover very extensive areas in Yukon, but they have a somewhat wide distribution and, in places, apparently constitute remnants of once larger areas, now infolded with older terranes; in most cases, however, they represent deposits laid down in separate basins of deposition. The fossil plant remains found in these beds, show that most of them, at least, are of fresh water origin.

These Tertiary rocks, in most places, are but little disturbed, although locally they have suffered considerable deformation. They consist, typically, of light-coloured, slightly coherent conglomerates and sandstones and dark to light-coloured, soft shales and clays. Interspersed through the strata are numerous seams of lignite; and some beds contain an abundance of plant remains. In places, also, volcanic material occurs associated with the slightly consolidated sediments.

These lignite-bearing Tertiary beds appear to all belong to the Kenai series,* which is the oldest known Tertiary in Yukon and Alaska, and is generally referred to the Upper Eocene. Since, however, Kenai beds, in places, rest conformably upon the Upper Cretaceous, and form with it a continuous series without any noticeable stratigraphic break, it is possible that the Kenai includes some lower Eocene. Since, also, the Kenai beds contain seams of lignite, it is customary to include in that formation all Tertiary beds containing coal. It would thus seem possible that rocks more recent than Eocene have been, in places, included in the Kenai, just as has happened at times in connection with certain lignite-bearing Cretaceous beds. On the accompanying map, only areas containing beds thought to belong to the Kenai series, are represented as Tertiary, as these are the only Tertiary members so far found to contain coal of economic importance.

In Yukon, Mr. A. J. Collier of the United States Geological Survey, in 1902, collected fossil leaves from the vicinity of Coal creek, a tributary of Yukon river, which were referred by Dr. F. H. Knowlton to the Upper Eocene. The writer, in August, 1912, also collected fossil plant remains from the vicinity of the Sour Dough, mine on Coal creek, concerning which Dr. Knowlton states†:

"I have had the assistance of Dr. Arthur Hollick in the study of this collection, and although the material is not extensive or very well preserved, it is fortunately sufficient to fix the age as Kenai. Dr. Hollick has been engaged for two years on a complete study of the fossil flora of Alaska, and is, of course, very familiar with its various stages. He agrees without hesitation to the above age determination."

The lignite seams in the Kenai series are not confined to any particular horizon, but occur in all positions from top to bottom of the series. This is what might be expected if the Kenai beds were deposited in unconnected basins, in which case, the coal seams would not be formed in all the basins simultaneously, nor would they occupy similar positions in the series.

The Jura-Cretaceous sedimentaries consist mainly of conglomerates, quartzites, sandstones, graywackes, arkoses, tuffs,

*Collier, A. J.—"The coal resources of the Yukon, Alaska": Bull., U.S. Geol. Surv., No. 218, 1903, pp. 17, 19.
Brooks, A. H.—"The geography and geology of Alaska": Prof. paper, No. 45, 1906, pp. 237-244.
†Personal communication.

shales and slates, having a wide range of colour and differing greatly in the amount of metamorphism they have suffered. In general they are considerably more indurated, and the beds have been much more disturbed than those of Tertiary age. In places the sandstones are decidedly quartzitic in character, and the shales have become altered into true slates with pronounced secondary cleavages. Near the southern boundary of Yukon, these Jura-Cretaceous beds are associated with great amounts of tuffs, which, in places, are quite massive, and, in the field, possess much more the general appearance of volcanics than of sediments. Toward the north, the volcanic materials gradually give place to true sediments, and on Peel and Porcupine rivers, neither Jurassic nor Cretaceous tufaceous rocks have been observed.

The Jura-Cretaceous beds of Yukon appear to be remnants of once more extensive areas, which, possibly, were originally all connected, but have been reduced by erosion to their present proportions. Sections of these rocks, except where widely separated, are thus generally somewhat similar, and certain easily recognizable members have been found to persist for hundreds of miles. The coal measures are thus everywhere confined to the same definite well-marked horizons, and, consequently, prospecting for coals in these rocks, is rendered much less difficult and uncertain than in the Kenai beds.

In Southern Yukon, where these Jura-Cretaceous rocks have been most studied, the uppermost member is composed dominantly of cherty conglomerate beds, which, in places, have an aggregate thickness of as much as 1,000 feet, and it is in these beds or within a zone extending 200 to 300 feet below them that all the Jura-Cretaceous coals of importance have been discovered. In prospecting for coal in Southern Yukon it is advisable, therefore, to search well all areas of these cherty conglomerates, which may be distinguished from all other Jura-Cretaceous conglomerates by their containing pebbles. In the case of these conglomerates the pebbles and boulders are all quartz and chert, and in all other conglomerates so far found in the district the pebbles are heterogeneous, including granodiorites and many types of volcanic rock. These cherty conglomerates thus constitute an exceedingly valuable horizon marker, and on geological maps they

have been differentiated, mainly for economic reasons, and have been designated the Tantalus conglomerates.* All the underlying Jura-Cretaceous beds are included in the Laberge series†.

A typical section is here presented of the Jura-Cretaceous beds of Southern Yukon showing the only two coal horizons of economic importance included in these beds—the upper and economically more important horizon being in the upper portion of the Tantalus conglomerates, and the lower horizon occurring in the Laberge beds 200-300 feet below the Tantalus conglomerates.

Concerning the age of these beds, there is still some uncertainty. A number of poorly preserved invertebrate remains were collected by the writer from the Laberge series in the Braeburn-Kynocks area where the name Laberge series was first employed. These fossils were examined by Dr. Whiteaves, who referred them to the Jurassic or Cretaceous.‡ In Wheaton district, Yukon, fossils were also collected from the Laberge rocks, which were referred to the Fort Benton group.§ Fossils were also collected from the Laberge rocks in Atlin district, B.C., of which Dr. T. W. Stanton writes:

> "These may possibly be Triassic, but I think it more probable that they are early Jurassic. They are certainly not so late as Cretaceous."‡

The only locality in Yukon in which fossils are known to have been found in the Tantalus conglomerates is at the Tantalus mine, where the writer collected some plant remains from the coal seams. These were examined by Dr. Penhallow who states

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*Cairnes, D. D.—"Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory": Memoir No. 5, Geol. Surv., Dept. of Mines, Can., 1910, pp. 35-38.

†Cairnes, D. D.—Op. cit., pp. 30-35.

‡Cairnes, D. D.—"Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory": Geol. Surv., Dept. of Mines, Can., Memoir No. 5, 1910, p. 35.

§Cairnes, D. D.—"Wheaton district," Geol. Surv., Dept of Mines, Can., Memoir No. 31, p. 56, 1912.

‡Gwillim, J. C.—"Report on the Atlin mining district, British Columbia": Geol. Surv. of Can., Ann. Rep., Vol. XII., 1899, Pt. B., p. 26.

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THE
YUKON COAL FIELDS
BY D.D. CAIRNES
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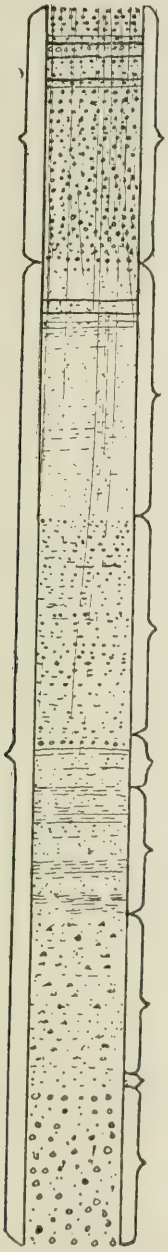
Areas throughout which Tertiary beds have been observed
Areas throughout which Tertiary beds probably occur
Areas throughout which Jura-Cretaceous beds have been observed
Areas throughout which Jura Cretaceous beds probably occur
Coal Outcrop.
BEAUFORT SEA
ARCTIC AREA
OLD CROW BASIN
BONNET PLUME COAL AREA
ROCK CREEK COAL AREA
SOUR DOUGH MTN.
DAWSON
INDIAN RIVER COAL AREA
SIXTY MILE RIVER AREA
SELKIRK COAL AREA
TANTALUS COAL AREA
BRAZEAU-TRUCKS COAL AREA
KLUANE DISTRICT
WHITEHORSE COAL AREA
Whitehorse
GREAT PLAINS AREA
NORTHWEST TERRITORIES
YUKON
ALASKA
BRITISH COLUMBIA
Peel R.
Porcupine River
Bonnet Plume R.
Klondike R.
Stewart R.
Hootalinqua River
Pelly River
Yukon R.
Kluane L.
Aishihik L.
Upper Liard R.
Liard R.
Teslin Lake
Lake Laberge
Fraser R.
68°
66°
64°
62°
60°
145°
141°
139°
137°
135°
133°
131°
129°
127°
125°
123°

Typical section of Jura-Cretaceous beds along Nordenskiöld River



Tantalus Conglomerates, 1000 ft.

Cherty conglomerate, including coal seams of upper coal horizon.

White, coarse sandstone, with occasional intercalated dark shales, and coal seams of lower coal horizon, 1,000 ft.

Dominantly coarsely textured, soft, friable, dark sandstones, 800 to 900 ft.

Laberge Series, 3800 ft

Reddish, calcareous, sandstone and conglomerate, including thin seams of lignite, 100 to 200 ft.

Dark, thinly bedded shales, interbedded with hard, coarsely textured, dark, graywackes. Occasional thin seams of coal, 500 ft.

Light greyish-brown and greenish-blue, graywackes, and tufaceous sandstones with some interbedded dark shales, 650 ft.

Coarse, white calcareous sandstone, but slightly bedded, 50 ft.

Coarsely textured, heavy bedded, conglomerate, 600 to 700 ft.

that they "conform to the flora of Kootanie age."* Geologists are not yet agreed as to whether the Kootanie series is Lower Cretaceous or Upper Jurassic.

Thus the information concerning the age of the Laberge series and Tantalus conglomerates is fragmentary, and to some extent conflicting, but the weight of evidence indicates that the greater portion of these beds, at least, is of Jurassic age. Until more information is obtained, therefore, these beds cannot be more closely delimited as to age, than by using for them the broad term Jura-Cretaceous.

COAL FIELDS.

General.

Under "Coal Fields" all the areas in which coal has been found in Yukon will be briefly described, commencing at the north and west and proceeding south and east. In addition, a number of areas are considered in which, though not proved to be coal-bearing, contain Jura-Cretaceous or Tertiary beds that are lithologically similar to those of the proved areas, and which appear to include horizons that elsewhere are coal-bearing. It is quite possible that coal will be found in these areas when the beds have been more thoroughly explored and prospected.

For the sake of convenience in description each area described in this paper is given a specific name, some of these are old well-established names, but others are here applied for the first time.

Arctic Laramie-Cretaceous Area.

A broad belt of Cretaceous and Laramie rocks fringes the Arctic extending to the west as far, at least, as longitude 148°, and reaching eastward to Cape Parry. This includes the whole

*Cairnes, D. D.—Geol. Surv., Dept. of Mines, Can., Memoir No. 5, 1910, p. 38.

northern coast of Yukon territory. The rocks, according to the few observers who have reported upon them, appear to be mainly of Cretaceous age, but include, in places, some Laramie members. Lignite has been noted in places in this Arctic area, and has been observed at one point at least in Yukon, viz., in the vicinity of Baggage river.

This Laramie-Cretaceous belt includes the islands off the mouth of the Mackenzie, and extends up this river for some distance. Possibly the Cretaceous beds of the Arctic area are continuous with those of the Cretaceous area which occurs higher up the Mackenzie and extends up Peel and Porcupine rivers, as shown on the accompanying map.

Dr. G. M. Dawson writes:

"The Arctic coast, west of the Mackenzie, to longitude 148°, was explored by Franklin. The shore is described as low, but a short distance inland, there is a range of mountains running nearly parallel to it, comprising, from east to west, the Richardson, Buckland, British and Romanzoff chains. The low land, at least as far as the west end of the Richardson chain, is probably underlain by Cretaceous or Laramie rocks, continuous with those of the Mackenzie basin, as beds of lignite were observed at Garry island off the mouth of the Makenzie, and near Baggage river, opposite the west end of the Richardson chain."—(2nd Exp. appendix, p. xxiii.)*

Old Crow Tertiary Basin.

According to Mr. R. G. McConnell,† of the Canadian Geological Survey, soft, incoherent rocks outcrop along Porcupine river in the vicinity of the Old Crow mountains for a distance, in a direct line, of forty-two miles. No fossils were found in the beds, but they resemble the lignite-bearing Tertiary of other parts of Yukon and adjoining territories. They unconformably overlie Cretaceous beds, and "consist essentially of light coloured sands, sandy clays, clays and conglomerates, with occasional nodular beds of ironstone, and in one section held a small lignite seam. . . . . The Tertiary beds occupy basins in the older rock, and evidence an elevation of the land at the end of the Cretaceous period followed by prolonged denudation, and a subsequent

*Dawson, G. M.—Ann. Rep., Geol. Surv. of Can., 1886, p. 28 R.

†McConnell, R. G.—Ann. Rep., Geol. and Nat. Hist. Surv. of Can., Vol. IV., 1888-89, pp. 23D, 127D-128D.

depression, accompanied by the formation of the lakes in which they were laid down."*

Porcupine and Peel Rivers Cretaceous Area.

Cretaceous conglomerates, sandstones, shales, etc., extend from Fort McPherson westward to Peel river, thence down Bell river to the Porcupine and down the Porcupine to within about one-half mile of Fishing river, where the Old Crow Tertiary basin commences.† These beds are part of an extensive Cretaceous area which continues eastward along the Mackenzie to within seven or eight miles of Old Fort Good Hope or to about longitude 131° 40′ and extends up Peel river to the Tertiary Bonnet Plume coal area‡ (see accompanying map).

No coal seams have been found in these Cretaceous beds so far as the writer is aware, but carbonaceous material and even fine particles of coal were observed in the shales in places.

Bonnet Plume Coal Area.

The Bonnet Plume coal area extends southward along Bonnet Plume river for about 30 miles from its mouth, and stretches to the west to include portions of Wind and Peel rivers. The area is about 30 miles long, and near its southern boundary has a maximum width, from east to west, of about 20 miles. Owing to its extreme northerly position, and to the difficulty and length of time required to reach it, this area was almost unknown until 1905, when Mr. C. Camsell, of the Geological Survey, made a geologic and topographic reconnaissance of Peel river and its tributaries. The coals of this basin have not been developed, and practically the only information available of the area is included in Mr. Camsell's report.§

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*McConnell, R. G.—Ann. Rep., Geol. and Nat. Hist. Surv. of Can., Vol. IV., 1888-89, p. 23D.

†Op. cit., pp. 113D-129D.

‡Camsell, C.—Ann. Rep., Geol. Surv. of Can., Vol. XVI, 1904, pp. 41CC-46CC.

§Camsell, C.—Geol. Surv. of Can., Ann. Rep., Vol. XVI., Pt. CC, 1906.

The rocks of the basin, according to Mr. Camsell, "consist of thick beds of soft sandstone, with some thin seams of lignite, overlaid by more sandstone containing pebbles, with clay and some thick beds of lignite. The whole series has been gently folded into a number of anticlines and synclines."*

The thickest seam of lignite noted is 30 feet in thickness. This seam occurs near the top of the series and is "fairly persistent, appearing in two exposures four miles apart, with a shallow syncline between."† This seam "has been burnt for some distance along the bank of the river, and even across to the east side of Bonnet Plume river, and has so undermined the overlying glaciers as to cause extensive landslides. The large seam of lignite contains a fair quality of brown coal, which, when dry, burns readily, leaving a great deal of ash. The upper layers are separated by these seams of clay, but the lower part is very pure. Underneath the thirty-foot lignite seam, and separated from it by a thick bed of sandstone is another seam eight feet in thickness."‡

Other seams of lignite occupying extensive areas, occur in the rocks of this basin. They range in thickness from a few inches to six feet. In a cut bank on Wind river, about twelve miles below Mount Deceptive, a six-foot seam of lignite occurs, and is again exposed two miles below.

"The lignite is still in a primary stage of development, and shows the twigs and leaves of which it is composed, and even some blebs of resin.¶ Directly opposite the mouth of Mountain creek are the burning lignite beds noted by Count de Sainville on his map in 1893. It is impossible to say how long these beds have been burning, but for nearly a mile along the bank the lignite has been burnt away, and has so undermined the overlying glacial drift as to cause large landslides."***

It is thus evident that this area contains a great amount of valuable coal which though practically inaccessible at present, should be of great value in the future.

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*Camsell, C., Geol. Surv. of Can. Ann. Rep., Vol. XVI., p. 41 CC.
†Op. cit., p. 41CC.
‡Op. cit., pp. 41-42CC.
¶Op. cit., p. 27CC.
***Op. cit., p. 30CC.

*Rock Creek Coal Area.**

General.—The Rock Creek area is the most extensive area of Tertiary coal-bearing beds known in Yukon. Outcrops occur along the right limit of Klondike river above Rock creek, and the beds extend thence in a northwesterly direction in the form of a long narrow basin to a point beyond Cliff creek, a distance of about 70 miles; the area has a probable average width, as estimated by Mr. McConnell, of about ten miles.

The belt lies along the base of the Ogilvie range, and follows in a general way the course of Yukon river, but is separated from it by a narrow strip of older rocks. Though wide valleys are cut through the Tertiary beds by a number of streams which join the Yukon from the northeast, outcrops are scarce owing to the soft character of the rocks.

These beds, as before stated, belong to the Kenai series which is of Eocene and probably mainly Upper Eocene age. The rocks are dominantly soft, slightly coherent conglomerates and sandstones, alternating with dark and vari-coloured shales and clays, including some carbonaceous beds. Interbedded with them, are occasional lignite seams. In most places the beds are gently inclined, but they are not everywhere so, and, in places, the inclination changes abruptly both in degree and direction. High dips, and, in places, faulting, also occur. Where the beds are strongly folded the rocks are considerably indurated. On account of the paucity of outcrops no general section of these beds has been measured, and the thickness of the series is unknown.

One or more seams of lignite appear to be included in the beds throughout a great part, at least, of their extent, as lignite outcrops on Rock creek and its tributary, Coal creek, at the southern end of Rock Creek area; on Cliff creek at the northern end; at intermediate points on Twelvemile creek, Fifteenmile creek, and Coal creek; and is also reported to occur at a number

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*McConnell, R. G.—Geol. Surv. of Can., Sum. Rep., 1900, pp. 44A-48A; Ann. Rep. Vol. XIV., p. 23B; Sum. Rep., 1903, pp. 41-42.

of other localities. The total area underlain by lignite probably exceeds 300 square miles.

The coal has been developed at only three points, so far as the writer is aware, viz., at Cliff creek; on Coal creek, a tributary of Yukon river; and on Coal creek, a tributary of Rock creek, which, in turn, flows into Klondike river. Of these the properties on Cliff creek and Coal creek, branch of Rock creek, have not been worked for a number of years. The Sour Dough mine on Coal creek (tributary of Yukon river), is still in operation.

Cliff Creek.—Cliff creek is a small stream which enters Yukon river from the east, nine miles above the town of Fortymile and about fifty-eight miles below Dawson. A number of lignite seams were formerly mined on this creek, but have not been worked for the past eight years. Concerning this property, Mr. McConnell* writes:

"The workings are situated about a mile and three-quarters from the mouth of the creek and consist of two long tunnels with a number of drifts and 'upraises.' The lower tunnel is on the right side of the creek and the upper a short distance farther up the creek on the left side. The distance along the zone from the mouth of the first tunnel to the end of the second is 2,800 feet, and the seams appear to be continuous for this distance and probably extend much farther.

"The tunnel at the upper workings has been driven mostly along the lignite zone, for a distance of 800 feet. At one point, 225 feet from the mouth of the tunnel, the coal seams are bent to one side and probably faulted. The lignite zone, consisting of alternating beds of lignite, clay and carbonaceous shale, measures over forty feet in thickness in places. The included lignite seams vary in thickness from a few inches up to five feet. A section 300 feet from the mouth of the tunnel showed over eleven feet of coal, in seams separated by clay partings and beds. The beds have a nearly east-and-west strike and dip in a southerly direction at angles of from 50° to 75°."

"The dip of the beds in the lower workings is much less than in the upper, and in places they are almost horizontal."

"A section in the lower workings showed:

	Feet.	Inches.
Lignite, one thin parting	9	0
Shales	2	0
White clay	2	9
Alternating clays and shales	3	0
Grayish clay	13	0
Carbonaceous clay	3	3
Lignite, one parting	3	0
Carbonaceous shales and clays	6	0
Soft sandstone with layers of grit	10	0
	51	0

*McConnell, R. G.—Sum. Rep., Geol. Surv. of Can., 1900, p. 46-48.

The following analyses were made by Dr. Hoffmann, of the Geological Survey:

	Upper Working.	Lower. Working.
Hygroscopic water	8.57	10.58
Volatile combustible matter	42.04	40.10
Fixed carbon	45.77	46.74
Ash	3.62	2.58
	100.00	100.00
Coke, per cent.	49.39	49.32

Coke of lignite from upper working—feebly coherent, tender.
Coke of lignite from lower working—non-coherent.

Coal Creek (Tributary of Yukon River).—Coal creek joins Yukon river from the east, 4 miles above Cliff creek, and 54 miles below Dawson. The creek forks 6 miles from the Yukon, and follows a general westerly course, flowing nearly due west below the forks. Coal occurs on both branches, but has been developed on the south fork only, on which the Sour Dough mine is situated, about 12 miles from the mouth of the creek.

Coal is believed to have been first located there by Henry Siemer about the year 1900; James Williams also became interested in 1902. Originally there were two adjoining holdings, those of the Coal Creek Coal Company and of the Sour Dough Coal Company, which were owned or operated by Williams and Siemer, respectively; later Mr. D. A. McRae became interested in the properties.

A narrow-gauge railway was completed from the mines to the mouth of Coal creek in 1904, and in 1905, the first coal was shipped.

In 1907, the properties of the two companies were acquired by Messrs. Grant and Fuller, of Dawson, under the name of the Sour Dough Coal Company. This company sold their interests in 1909 to the Northern Power and Light Company, which still owns the property, generally known as the Sour Dough coal mine. Mr. E. H. Thruston, of London, England, is managing director and Mr. G. G. Hulme, of Dawson, is secretary and general manager of the company.

The coal seams outcrop in the creek banks near the western edge of the Rock Creek area, and but a short distance west of the

mine, the Tertiary coal-bearing beds overlie, unconformably, pre-Devonian schistose rocks. The beds at the mine, as mentioned previously, have been determined, from the plant remains collected from them, to belong to the Kenai series, and consist mainly of light coloured, friable, slightly coherent sandstones, and light and dark coloured, soft shales and clays. All the beds on being exposed to the atmosphere rapidly decrepitate to form sand and clay.

The property here included under the term Sour Dough mine, has been reported on by Mr. R. G. McConnell* and Mr. A. J. Collier,† of the Canadian and United States Geological Surveys, respectively. The reports made by these geologists describe the early workings on the property, and include much valuable information concerning conditions in that vicinity ten years ago.

In August, 1912, the writer visited the Sour Dough mine and the information in this paper concerning the property, is the result of a day spent there at that time.

On account of the heavy mantle of decomposed bed-rock and other superficial materials, which nearly everywhere cover the coal-bearing beds in the vicinity, it has not been possible to measure a section of these rocks. Consequently, it is not known how many coal seams occur, nor even how many seams the known coal outcrops represent. A number of old caved-in or partly filled workings occur along the east side of the creek above the present mine workings, but these afford little information. From the data available, however, three main seams appear to have been discovered and developed. Other less important seams occur. The three principal seams are designated the "Ten-foot," the "Sour Dough," and the "Old Sour Dough" seams. The Ten-foot seam has been found to vary from 5 feet to 14 feet in thickness, and averages approximately 10 feet. About 200 feet below this is the Sour Dough seam, which, in most places, is about 14 feet in thickness, but at one point is as much as 30 feet thick. The Old Sour Dough seam is 4½ feet below the Sour

*McConnell, R. G.—Sum. Rep., Geol. Surv. of Can., 1903, pp. 41, 42.

†Collier, A. J.—"The coal resources of Yukon, Alaska": U.S. Geol. Surv., Bull. 218, 1903, pp. 25, 26.

Dough, and is, in most places, about 12 feet thick. The coal in all three seams is very similar in quality.

The present owners are mining on both sides of the creek, the property on the east being known as No. 1 mine, and that on the west as No. 2 mine. At No. 1, only the Ten-foot seam is being mined, and this is worked by the pillar-and-stall method, with level entry, which has been driven from the surface, 1,460 feet on the seam. In all, over 4,000 linear feet of work have been there performed. A typical section of the Ten-foot seam was measured, and showed as follows:

Coal	2	feet	6	inches.
Shale	0	"	6	"
Coal	4	"	6	"
Shale	0	"	1	"
Coal	1	"	7	"
Shale	0	"	5	"
Coal	2	"	0	"

At No. 2, the Sour Dough and Old Sour Dough seams, only are being worked. These are mined by the pillar-and-stall method, and the coal is hoisted to the surface up a slope sunk on the lower seam to the main gangway. In August, 1912, work was being performed at No. 2 mine, at the rate of 200 feet per month, with a daily coal production of 100 tons. In all, about 1,500 linear feet of work had been there performed, including the slope, gangways or main levels on the two seams, inclined stalls, and cross headings.

Both the Sour Dough and the Old Sour Dough seams contain, in most places, one to three clay partings, having an aggregate thickness of 5 to 10 inches in each seam.

Three samples, taken by the writer from these seams, were assayed by the Mines Branch, Department of Mine, Ottawa. These samples were selected as follows:

No. 1, average sample of upper 8 feet of Old Sour Dough seam.
No. 2, average sample of Sour Dough seam.
No. 3, average sample of lower 6 feet of Old Sour Dough seam.

Separate samples were necessarily taken for the upper and lower portions of the Old Sour Dough seam, since no complete section of this seam was exposed.

Proximate analyses by fast coking gave the following results:

	1.	2.	3.
Water	17.10	17.20	14.57
Volatile combustible matter	34.50	33.84	33.11
Fixed carbon	38.40	33.72	37.15
Ash	10.00	15.24	15.17
	100.00	100.00	100.00
Coke (non-coherent)	48.40	48.96	52.32
Fuel ratio	1:1.11	1:0.996	1:1.2

During 1910 and 1911 about 10,000 tons of coal were mined each year, and about 6,500 tons were produced during the past summer (1912).

The present owners of the Sour Dough mine, operate a narrow-gauge railroad between the mine and the mouth of Coal creek, and have their own steamer and barges for transporting coal, supplies, and equipment on Yukon river.

In August last (1912), 40 men were employed in connection with the mine, including those on the railway. The wages paid per day with board and lodging included, was $5.00 to miners, and $4.00 to men performing ordinary surface labour.

In addition to the above-mentioned equipment, a power plant has been installed, or, at least, partly installed, on the Sour Dough property. This plant is designed to produce 12,000 horse-power, and is reported to have cost $2,500,000. The plant includes:

Six 2,000 horse-power Babcock and Wilcox boilers with induced draft and mechanical stokers. Four of these boilers only were installed.

Three 2,000 K.W. Siemens Brothers generators—one actually installed.

Two 1,000 K.W. British Westinghouse generators.

Two 500 K.W. British Westinghouse generators.

In addition, there are transformers, regulators, several small motors, machine shop, etc.

A pole line 39.5 miles long was constructed to carry the power to Dawson—the power to be generated at 6,600 volts and transmitted at 33,000 volts.

The plant was constructed, as it now stands, in 1910, and ran from early in September to about December 20th, and again for about 40 days in May and June, 1911, but has since been shut down. It was installed mainly for the purpose of generating power for use in mining operations in Klondike district. The Granville Power Company, however, have installed a hydro-electric power plant driven by water derived from the north fork of Klondike river, and are able to produce somewhat cheaper electric power than the Northern Light and Power Company, who generate their power from coal. Consequently the Coal Creek plant cannot compete, at present, and is closed.

Coal Creek (Tributary of Rock Creek.)—A coal property was formerly worked on Coal Creek (tributary of Rock creek) at a point about 7 miles from Klondike river measured along Rock creek and Coal creek valleys, and 20 miles from Dawson.* This property has not been operated for some years.

Lignite outcrops there in the face of a low rounded hill where the rocks have been exposed by stream erosion. The rocks are mainly slightly coherent, micaceous sandstones and brownish clays holding a broken bed of lignite. "The workings of the mine consist of an incline about 400 feet in length. . . . A short drift has been driven in a north-easterly direction, following the seam, at a point 225 feet from the mouth of the incline. The seam dips to the northeast in the drift at angles of from 3° to 10°. . . . Two seams of lignite are present in the lower part of the incline and in the drifts. . . . The two seams are separated by a clay parting about a foot thick and are roofed and floored with clay. The lignite is hard and compact and shows no traces of the woody fibre so common in lignites. It is probable, as suggested by Dr. Hoffmann, that it originated largely from mosses and other low forms of vegetable growth. It is of good quality, burns freely and can be used both for heating and steam purposes."†

*This property was reported on by Mr. McConnell, of the Geological Survey of Canada, and the information here given is taken mainly from his report. McConnell, R. G.—Sum. Rep., Geol. Surv. of Can., 1900, pp. 45, 46.

†Op. cit., pp. 45, 46.

The following are the results of analyses of these coals made by Dr. Hoffmann in the laboratory of the Geological Survey:

Lignite from upper seam, Coal Creek mine:

Hygroscopic water	18.31
Volatile combustible matter	34.96
Fixed carbon	40.88
Ash	5.85
	100.00
Coke percentage (non-coherent)	46.73

Lignite from lower seam, Coal Creek mine:

Hygroscopic water	19.37
Volatile combustible matter	33.85
Fixed carbon	37.45
Ash	9.33
	100.00
Coke percentage (non-coherent)	46.78

Sixtymile River Tertiary (?) Area.

A large area on Sixtymile river is covered by beds which were referred, tentatively, to the Tertiary, by McConnell.* The eastern apex of this area touches Yukon river below the mouth of Indian river. On the accompanying map the provisional Tertiary classification of this area is retained, although it is possible the beds are of Jura-Cretaceous age.† The rocks consist dominantly of sandstones and shales, associated with andesites and rhyolite tuffs. No coal has as yet been discovered in the area, although some of the beds are quite similar to those associated with coals in other portions of Yukon.

Indian River Coal Area.

Tertiary beds "cover a considerable area south of Indian river, above and below the mouth of Quartz creek. They occupy here a remarkable depression, surrounded on all sides, except where crossed by the Indian river valley, by high ridges built of the older schists. From the centre of the depression rise Haystack mountain and the Dismal dome, two prominent andesite cones, and a number of other lower andesite hills. The origin of the depression is probably due to volcanic action.

*McConnell, R. G.—Geol. Surv. of Can., Ann. Rep., Vol. XIV., 1901, p. 24B.

†McConnell, R. G.—Geol. Surv. of Can., Sum. Rep., 1901, Vol. XIV., p. 37A.

"The beds in this area are lightly folded and consist of soft, light-grayish, arkose sandstones, yellowish and dark tufaceous sandstones, light and dark shales and clays, agglomerates and conglomerates."* A narrow bed of lignite occurs in these beds on a property owned by McKinnon Bros., located on a branch of Ruby creek, a tributary of Indian river. A sample was taken from this seam and analysed by Dr. H. M. Payne, of New York, who kindly permits the publication of the result of the analysis:

Fixed carbon	13.96%
Moisture and volatile matter	24.40%
Ash	61.64%

Selkirk Coal.

Within the last few months, coal was discovered in the left bank of the Yukon at a point five miles above Selkirk. The coal is a good grade of lignite, and occurs in apparently Jura-Cretaceous rocks underlying Tertiary basalt flows. Up to August last, no development work had been done, and neither the widths of the seams nor their number, was known.

If the coal turns out well, and occurs in seams of workable thickness, it will be of considerable value, since it is situated immediately on the river, and between Tantalus and Five Finger mines and Dawson, and might thus afford an additional coaling point for river steamers.

Tantalus Coal Area.

General.—The Jura-Cretaceous beds of the Tantalus area outcrop along Lewes river about 10 miles below Five Fingers rapids. They probably extend to the north to the mouth of Mica creek on Pelly river, a distance of 30 miles, and are known to be developed to the south along Lewes and Nordenskiöld rivers for 60 miles.† The area is 50 miles wide in places and has an average width of 12 or 15 miles.

*McConnell, R. G.—Geol. Surv. of Can., Ann. Rep., Vol. XIV., 1901, p. 24B.

*Dawson, G. M.—Geol. Surv. of Can., Ann. Rep., Vol. III., 1887-88, pp. 36B, 148B, 149B.

†Cairnes, D. D.—"Preliminary memoir on the Lewes and Nordenskiöld Rivers Coal District, Yukon Territory": Geol. Surv., Dept. of Mines, Can., Memoir, No. 5, 1910, pp. 30-38.

The rocks of the area belong dominantly to the Laberge series which consists of conglomerates, sandstones, graywackes, tuffs, shales, slates, and quartzites. These are of many different colours and of varying degrees of hardness. The Tantalus conglomerates are, wherever they occur, remarkably uniform in appearance, due to the fact that the component pebbles or boulders are all composed of chert and quartz. The individual beds are also very evenly textured, as the pebbles, being all of materials having practically the same specific gravity, have been water-sorted during deposition. The section of Jura-Cretaceous beds along Nordenskiöld river, shown on a preceding page, is typical of the whole Tantalus area. The Tantalus conglomerates have an observed aggregate thickness of as much as 1,000 feet in places, though a complete section was nowhere seen, since the original top of the formation has been everywhere removed by erosion.

Coals occur at two horizons, as before stated,—near the top of the Tantalus conglomerates, and in a zone that lies 200 to 300 feet below them. The areas of most economic importance, therefore, are those in which the Tantalus conglomerates occur, and particularly those in which the upper coal horizon is preserved. Over considerable portions of the area, the conglomerates are partly or entirely eroded away, and, in places, the underlying coal horizon has also been removed.

Tantalus conglomerates outcrop on Lewes river at Tantalus, and form the main part of Tantalus butte on the opposite side of the river. They also extend for 2½ miles along the top of the ridge to the north of the butte, and beyond there are overlain by Carmack basalts, probably of Tertiary age. The conglomerates are also exposed along Lewes River valley for three-quarters of a mile to the southwest, and outcrop for nearly 2 miles to the east of Tantalus. They are exposed also for about a mile to the south of Tantalus, and after an interval of 2½ miles, where the bedrock is concealed by superficial deposits, are again exposed for a short distance. Farther south, more recent basalts and andesites cover the sedimentary formations in most places, and only at occasional points are the sedimentaries exposed. The conglomerates are developed on Lone Pine, Porter, and Montague moun-

tains,* and it is thought that they form practically a continuous belt extending along the east side of Nordenskiöld valley for 17 miles, the distance between these points, although for most of the distance they are covered by volcanics or superficial deposits.

Three coal properties occur in the Tantalus area, viz., Five Fingers and Tantalus mines where coal has actually been mined, and at Tantalus Butte.

Coal also occurs on Mica creek, concerning which McConnell writes: "East of Willow creek the Pelly winds through a wide depression" . . . which "extends southward along Mica creek, the outlet of Tatlmain lake and may be underlain by the Cretaceous coal-bearing rocks which cross the Lewes at Five Fingers rapids.

"A shaft sunk on an easterly branch of Mica creek, about eight miles from the Pelly, is reported to have passed through several small seams of lignite."†

In addition, coal seams outcrop along the east side of Nordenskiöld river, 13 miles south of Tantalus, also 4 miles farther south, on Porter mountain (see map of Tantalus coal area). At the first of these points, seams belonging to the upper coal horizon outcrop, but their thicknesses were not determined, on account of the heavy covering of superficial materials.

On the south side of Porter mountain, the lower portion of the measures of the upper horizon is exposed, the upper part having been removed by erosion. The measures are considerably folded and disturbed by an intrusion of syenite-porphyry, which outcrops over most of Porter mountain, and the coal is changed in quality from a lignite, or bituminous coal, to an anthracite. Some prospecting work has been done on this coal, which is locally known as "Porter's Coal." Although the most important seam found is only about 16 inches in thickness, it is possible that other and better seams exist, hidden under the heavy drift cover. An average outcrop sample of the 16-inch seam, analysed by Mr. F.

*See map of "Tantalus Coal Area," accompanying following report:
Cairnes, D. D.—"Preliminary memoir on the Lewes and Nordenskiöld Rivers Coal District, Yukon Territory": Geol. Surv., Dept. of Mines, Can., Memoir No. 5, 1910.

†McConnell, R. G.—Geol. Surv. of Can., Sum. Rep., 1902, Vol. XV., 30A, 38A.

(*Photo by H. M. Prague.*)

Tantalus Mine.

G. Wait, of the Mines Branch, Department of Mines, was found to contain:

Water.	Vol. Combustible Matter.	Fixed Carbon.	Ash.
4.68	15.59	72.26	7.47

Five Fingers Mine.—The property is owned by the Five Fingers Coal Company,* and is situated on the right bank of Lewes river, 16 miles below Tantalus, by river, or 8 miles as the crow flies. Some years ago, a slope was sunk about 350 feet on the best seam so far found in these measures, and a number of rooms were driven off this entry. The seam dips to the east at an angle of 16°; and in the lower rooms is 3½ to 4 feet thick. A considerable amount of coal was mined and sold, chiefly in Dawson, but the workings have now been closed for several years.

As the top of this old slope is situated in the steep clay and sand bank of the river, and is, therefore, unstable, when work was resumed under new management in 1906, the entrance was shifted to safer ground, some distance to the south. The new slope was sunk 783 feet, on a seam which also dips at 16° to the east, and is higher in the measures than the seam in the old workings. This upper seam, though in places not more than 6 inches thick, shows at the bottom of the slope 22 inches of good clean coal, and 24 inches of coal and shale.

During 1907 and 1908 very little work was done on the property. In the former year a 26 ft. winze was sunk at a point 450 feet down the new slope, to a coal seam 4 ft. 6 in. thick, which is apparently the same seam as that in the old workings. Since 1908 the mine has been closed.

The following samples were taken by the writer: Sample A represents an average of the 22 inches of good coal in the bottom of the 783 ft. slope; and B an average of the bottom of the 26 ft. winze. Assayed by the Mines Branch, Department of Mines, at Ottawa, these samples gave the following results:

Sample.	A.	B.
Water	5.95	5.29
Volatile combustible matter	40.46	36.14
Fixed carbon	45.16	40.12
Ash	8.43	18.45
	100.00	100.00

*The head office of the Five Fingers Coal Company is in St. Paul, Minn., Mr. Geo. J. Milton being general manager.

Coke, per cent.	53.59	58.57
Character of coke	Firm, coherent	...
Ratio of volatile combustile to fixed carbon	1 to 1.11	1 to 1.11
Colour of ash	Reddish	Reddish
Kind of fuel	Coal	Coal

Tantalus Butte.—On Tantalus butte, across the river from Tantalus mine, the measures of the upper coal horizon outcrop. The beds dip to the west, and the coal outcrops are near the top of the butte, and generally 300 or 400 feet above the river,—superficial deposits covering the formation lower down. A section of a portion of the measures exposed is as follows:

Heavy massive conglomerate beds, at least 200 feet thick, forming top of the butte.

	Feet.
Shales, sandstones, etc., including an 8 ft. 10 in. seam of coal....	70
Conglomerate	60
Shales, sandstones, etc., including a 9 ft. 10 in. seam of coal near the top, and a 7 ft. seam near the bottom; total thickness	160
Conglomerate	80
Finer sandstones, shales, etc.	100
Conglomerate, bottom not seen.	

Average outcrop samples of the 8 ft., 10 in.; the 9ft., 10 in.; and the best 6 feet of the 7 ft. seam, numbered respectively, A, B, and C, were analysed in the laboratory of the Mines Branch, Department of Mines, at Ottawa, with the following results:

	A.	B.	C.
Water	13.64	16.32	12.87
Volatile combustible matter	31.83	31.72	31.72
Fixed carbon	51.84	42.13	49.51
Ash	2.69	9.83	5.90
	100.00	100.00	100.00
Ratio of volatile combustible matter to fixed carbon	1.63	1.33	1.56
Potash reaction	Dark	Brownish	Red
Colour of ash	Pale reddish brown	Pale brownish yellow	Yellowish brown
Kind of fuel	Lignite	Lignite	Lignite

These do not give a coherent coke.

No development work has been performed on this property other than a limited amount of surface prospecting, including a few trenches, open-cuts, etc.

Tantalus Mine.—Tantalus mine is situated on the left bank of Lewes river about 190 miles below Whitehorse. It is about 2 miles, in an easterly direction, from Carmack's roadhouse, on the Whitehorse-Dawson waggon road, 131 miles from Whitehorse.

The coal outcrops in the river banks and is, therefore, well situated for economical working. The cars are hauled out of level entries by mules, and by means of a cable, operated by a small stationary steam engine, are pulled up an incline, at the top of which the coal is dumped into bunkers ready for loading into river boats. Three seams have been opened up, only the lower two of which have been worked to any extent. The seams vary somewhat in thickness, but average, perhaps, 7 ft. 6 in., 6 ft. 6 in., and 3 ft. of coal in the bottom, middle, and top seams respectively. The lower two seams have, in places, not more than 4 feet of rock between them, and the middle and top seams are generally about 7 ft. apart. The coal is worked by the pillar-and-stall system, from two level entries, which have been driven about 2,000 feet. The beds in the mine workings, dip to the east at angles ranging from 24° to 40°.

In 1908, the writer took a 500-pound sample from each of the three seams. These were treated and analysed by the Mines Branch,—the following being part of the results of this work.*

	Upper Seam.		Middle Seam.		Lower Seam.	
	Raw.	Washed.	Raw.	Washed.	Raw.	Washed.
	%	%	%	%	%	%
Moisture in sample as received in laboratory	0.9	..	0.7	..	0.7	..
Proximate Analysis of coal dried at 105° C—						
Fixed carbon	58.0	59.9	54.1	60.3	56.0	59.2
Volatile matter	25.0	26.3	26.7	25.7	27.8	28.1
Ash	17.0	13.8	19.2	14.0	16.2	12.7
Ultimate analyses of dried coal—						
Carbon	69.8	...	...	...	71.1	...
Hydrogen	4.0	...	...	...	4.3	...
Sulphur	0.5	0.5	0.5	0.4	0.5	0.5
Nitrogen	0.8	0.8	0.9	0.8	0.7	0.8
Oxygen	7.9	...	...	...	7.2	...
Ash	17.0	...	...	...	16.2	...
Calorific value of dried coal in calories per gram	6,700	7,110	6,310	7,070	6,790	7,210

*For the complete results of the tests made of these fuels see the following reports:

Cairnes, D. D.—"Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory": Geol. Surv., Dept. of Mines, Can., Memoir No. 5, 1910, Appendix III., pp. 59-63.

Porter, J. B., and others.—"A investigation of the coals of Canada": Mines Branch, Dept. of Mines, Can., 1912, Vol. I., p. 153, Table XLIV.; Vol. II., Table LXX.

The number of tons of coal produced from this property during the past few years is approximately as follows:

Year:						
1906.	1907.	1908.	1909.	1910.	1911.	1912.
5,170	8,500	4,500	3,500	3,000	3,500	3,000

Pelly River Areas.

Rocks considered by Dawson to be of Laramie or Cretaceous age outcrop on Pelly river 27½ miles west of Ross river. "They consist of black carbonaceous or possibly plumbaginous shales, rather hard, and interbedded with grey-brown sandstones."* No coal was found in these rocks, possibly on account of the scarcity of outcrops.

Also, in the vicinity of Gull rock, in Granite canyon, on Pelly river, soft, yellowish, tufaceous sandstones and dark carbonaceous shales occur associated with andesites. These carbonaceous beds, near Gull rock, pass into an impure lignite, and are "probably of the same age as the lignite-bearing beds at Five Fingers rapid, which hold Cretaceous fossils."†

Braeburn-Kynocks Coal Area.

Braeburn-Kynocks area lies to the east of and adjoins the lower end of Lake Laberge (see map of Braeburn-Kynocks coal area).‡ Jura-Cretaceous beds extend over the greater portion of this area, but except in the western portion, in the vicinity of Klusha creek and Schwatka river, the coal horizons, if they ever existed, appear to have been removed by erosion. In the southwest portion of the area, however, the Tantalus conglomerates are quite extensive and occur in the form of two main northwesterly-trending belts, one of which is crossed by Klusha creek and the other by Schwatka river. These areas are about 12 and 10 miles long, respectively, and have average widths of about 1 to 1½ miles. The more southerly (10-mile) belt does not termin-

*Dawson, G. M.—Geol. and Nat. Hist. Surv. of Can., Ann. Rep., Vol. III., Pt. I., 1887-88, p. 126B.

†McConnell, R. G.—Geol. Surv. of Can., Sum. Rep., 1902, Vol. XV., pp. 31A, 38A.

‡This map accompanies the following report:

Cairnes, D. D.—"Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory": Geol. Surv., Dept of Mines, Memoir No. 5, 1910.

ate at the western edge of the Braeburn-Kynocks map-area, but continues to the westward into unexplored territory.

The conglomerates overlie conformably the beds of the Laberge series in the form of a large, broken, flat, undulating cake, which forms the tops, and, in places, the main portions of a number of hills and ridges.* Here the upper portion of the Tantalus conglomerates, including the upper coal horizon, has been eroded away, in most places at least. But since the lower horizon,—that of the upper Laberge beds,—is generally only about 200 or 300 feet below the Tantalus conglomerates, it follows that this horizon underlies all the conglomerate beds in the locality, and would outcrop in the valleys or along the hillsides around the edges of the conglomerate areas, wherever the upper beds of the Laberge series are not below the valley bottoms, were it not that it is, in most cases, covered by volcanic and superficial deposits.

The coal measures of this lower horizon were seen outcropping along the northeast face of Red ridge, and are well exposed along a small creek on the northeast side of Division mountain. Here, one seam is 7 to 8 feet; one is 4 feet; and several are from 6 to 18 inches wide. Nos. 1 and 2 are average surface samples taken from the 18-inch, and the 7 to 8 ft. seams, respectively. Analysed by Mr. F. G. Wait, of the Mines Branch, Department of Mines, at Ottawa, the following are the results of these samples:

	Water.	Volatile Combustible Matter.	Fixed Carbon.	Ash.	Fuel Ratio.
No. 1	8.98	29.62	48.30	13.10	1:1.63
No. 2	12.02	34.28	42.56	11.14	1:1.24

These coals are classed by Mr. Wait as lignites.

Other coal seams may probably occur here, as superficial materials obscure the bedrock over considerable portions of the area.

Kluane District.

Sedimentary rocks which are referred by Mr. McConnell† to the Tertiary, occur in Kluane mining district. The beds are

*Cairnes, D. D.—Op. cit., pp. 37, 49, 50.

†McConnell, R. G.—Geol. Surv. of Can., Sum. Rep., 1904., Vol. XVI., p. 7.

developed in two areas, one on Kimberly and Telluride creeks, and the other at the head of Sheep creek. The first area is six miles, and the other about five miles long; each has an average width of about two miles. The rocks consist mainly of tuffs, gray sandstones, grits, conglomerates, and dark shales, which include occasional lignite seams. The Sheep creek beds are less indurated than those on Kimberly creek, they include a larger portion of tuffs, and occur in brightly coloured alternating green, red and brown bands. According to Mr. McConnell, these rocks are very similar to the lignite-bearing beds in the vicinity of Dawson. They are strongly folded and have been affected by the principal mountain-making movements which produced the St. Elias range.

One of the lignite seams on upper Sheep creek is over four feet in thickness. "The lignite is of excellent quality and burns freely in an ordinary Yukon box stove. There is no wood along the upper portions of the creek and lignite is used by the miners for fuel. Lignite also occurs on Kimberly creek, but is not well exposed."*

Whitehorse Jura-Cretaceous Area.

General.—Jura-Cretaceous beds are extensively developed in Whitehorse and Conrad mining districts to the south and southwest of Whitehorse. These beds were originally described under the name Tutshi series,† a series which includes both the Laberge series and Tantalus conglomerates. Later, the writer re-mapped the southwestern portion of the area and sub-divided the Tutshi series.‡ In only two localities in this portion of Yukon territory, however, have coal measures been found, viz., in the vicinity of Coal lake, and on Mt. Bush, to the west of Annie lake. In the Coal lake vicinity, a group of claims have been located which constitute the "Whitehorse Coal" property. At both of these places, the coal measures occur in the Tantalus conglomerates, and correspond to those of the upper coal horizon in Tantalus and Braeburn-Kynocks areas.

*McConnell, R. G.—Geol. Surv. of Can., Sum. Rep., 1904, Vol. XVI., p. 18.

†Cairnes, D. D.—"Report on a portion of Conrad and Whitehorse Mining districts, Yukon": Geol. Surv., Dept. of Mines, Can., 1908, pp. 31-36.

‡Cairnes, D. D.—"Wheaton district, Yukon Territory": Geol. Surv., Dept. of Mines, Can., Memoir, No. 31, 1912, pp. 53-59.

Whitehorse Coal.—Claims known as the "Whitehorse Coal" property, were located just west of Coal lake, about ten years ago. The eastern boundaries of these claims are almost directly west of Cowley, on the White Pass and Yukon Railway, and are about 10 miles west of the nearest point on the railway.

Several seams of anthracitic coal outcrop on this property, on the north side of the pass at the head of Coal creek. They strike about N. 63° W. (astronomic) and dip to the northwest at angles ranging from 40° to 45°. The measures appear to be fairly regular, and were followed for over five miles to the northwest of Coal lake, and it is claimed that they extend seven miles farther. The measures also outcrop to the east of Coal lake, but have not there been developed nor prospected.

Three main seams have been found, which where exposed are 9 ft., 8 in.; 10 ft., 4 in.; and 2 ft., 6 in. in thickness. It is probable that other seams occur, but the mantle of superficial materials which covers the measures in this vicinity, have prevented their discovery. A tunnel 60 ft. long has been driven on one of these seams, and a few open-cuts, and trenches have been dug; otherwise the property is entirely undeveloped.

Three samples were taken from the seams, as specified below. These were analysed in the laboratory of the Geological Survey of Canada, at Ottawa, with the following results:

A is an average sample of the 9 ft., 8 in., seam at the end of the 60-foot tunnel.

B is an average sample of the 2 ft., 6 in. seam.

C is an average outcrop of the 10 ft., 4 in., seam.

	A.	B.	C.
Water	2.15	3.76	3.78
Volatile combustible matter	6.01	8.34	10.06
Fixed carbon	69.86	62.50	38.38
Ash	21.98	25.40	47.78
	100.00	100.00	100.00

This coal occurs within easy reach of the town of Whitehorse and the Whitehorse Copper deposits, and is also only a few miles from Wheaton mining district. The property is also quite accessible as there is a good grade to it from the W. P. and Y. Railway. The coal should, therefore, be of considerable importance in the future.

*Mt. Bush Coal.**—The coal measures of Mt. Bush† outcrop on the east side of Mt. Bush about one mile west of the Union mines, and 2½ miles west of Annie lake (see map of Wheaton district).‡ Coal was first discovered here by the writer in 1906,§ but the seams were not then measured or uncovered. The locality was visited again in July, 1909, when three seams were uncovered, and float coal was observed, which seemed to have been derived from other seams. The coal was deeply covered with frozen superficial materials in which digging was slow and laborious work. Only the three seams were uncovered, and these not for their entire widths. The property has since been staked, and the owners are reported to have performed considerable development work.

At Discovery, one 18-inch seam, and one at least 6 feet thick were uncovered; but the hanging-wall of the larger seam was not found. A portion, 3 feet thick, of another seam was also stripped, and the hanging-wall appeared to be still 2 to 4 feet distant.

The coal measures occur in Tantalus conglomerates which extend over an area about 2 miles long and one-third mile wide at the widest point. The rocks are considerably distorted, and disturbed, but strike in a general northerly direction, and are inclined at 60° to 80° to the west. A fine-grained, greenish, andesite dike about 15 feet wide, cuts the measures, and adds to their irregularity.

The Tantalus conglomerates extend down to near the creek bottoms on both sides of the ridge on which the coal was found, and also appear to the south, across Schnabel creek, on Mt. Folle. An easterly-dipping, normal fault, having a displacement of at least 5,000 feet, however, occurs to the west of the coal-outcrops, so that if the coal seams persist downward sufficiently far, they will encounter this break and be cut off, at a depth, measured

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*Cairnes, D. D.—"Wheaton district, Yukon Territory": Geol. Surv., Dept. of Mines, Can., Memoir, No. 31, 1912, pp. 145-147.

†The Mt. Bush area is represented on the accompanying map by the most southerly of the indicated coal outcrops in "Whitehorse coal area."

‡This map accompanies writer's report on Wheaton district.

§Cairnes, D. D.—"Report on a portion of Conrad and Whitehorse mining district, Yukon": Geol. Surv., Dept. of Mines, Can., 1908, pp. 32. 33,

along the seams, of 1,500 to 2,000 feet from discovery. The strike of the coal-measures is also approximately parallel to the trend of the fault.

No evidence of coal was found in the Tantalus conglomerates on Mt. Folle.

An outcrop sample taken from the 6-foot seam was analysed by the Mines Branch of the Department of Mines at Ottawa. The following is the result of the analysis:

Moisture	4.78 per cent.
Volatile matter	8.62 " "
Fixed carbon	56.50 " "
Ash	30.10 " "
	100.00

This shows that the coal is a semi-anthracite. The high ash is probably partly due to the fact that the sample was derived from the frozen outcrop of the seam, and contained sand and other extraneous materials.

Frances and Liard Rivers Tertiary Basins.

Grey and whitish, Tertiary clays and shales associated with lignite occur along the Upper Liard river from a point about six miles above the Lower Canon* to the mouth of Frances river, a distance in a direct line of 21 miles or about 31 miles by the river. "The thickest bed of lignite observed was about three feet, four miles below the Frances. The lignite is generally impure and often distinctly laminated. It resembles in character the lignites of the Miocene of British Columbia, and the associated clays and soft shales are similar in character to those of that formation. . . . The shaly clays and lignites show evidence of considerable disturbance, and dip in some places at rather high angles. This may be due to the action of old landslides along the banks of the river, but appears to be rather too constant to be satisfactorily accounted for in that way."†

Many small exposures of Tertiary shales and clays of grey, blackish, and yellowish tints, occur along Frances river from its mouth to within about a mile of the Middle Canon, a distance measured in a direct line of 12 miles, or about 25 miles by the

*The lower edge of the Lower Canon occurs near the British Columbia-Yukon boundary line, the 60° parallel.

†Dawson, G. M.—Geol. and Nat. Hist. Surv. of Can., Ann. Rep., Vol. III, 1887-88, p. 101B.

river. "Lignite is strewn in great quantities over some of the bars, and though thin seams occur in places in the banks, it is probable that thicker ones exist in the bed of the river. The lignite often holds drops of fossil resin or amber."*

This Tertiary basin has a length in Yukon territory of at least 25 miles. It also extends to the south into British Columbia, and possibly extends some distance to the north. The width of the area is indefinite, but was thought by Dawson to be about 15 or 20 miles.

Soft, light and dark coloured clays and shales, and friable sandstones and conglomerates, with interbedded seams of lignite occur just south of the 60th parallel along Liard river below the mouth of the Dease to below Little Canon.† These beds probably extend to the north into Yukon to the extent, at least, that is indicated on the accompanying map.

Great Plains Jura-Cretaceous Area.

Cretaceous beds extend along Liard river (in British Columbia and Northwest Territories) from Fort Liard, near the southeast corner of Yukon, almost to Devil's portage,‡ and the evidence available makes it seem probable that these beds extend into Yukon to the north as indicated on the accompanying map. These beds are a northerly extension of the great Cretaceous coal-bearing area of the Great Plains to the south and southeast.§

SUMMARY.

In order to make the information concerning the Yukon Coal Fields as complete as possible, areas have been described that are not now, and possibly never will be, of economic importance as coal producers. However, some of these areas are practically unprospected, and none have been at all thoroughly explored. It is not known, therefore, how important such areas of Tertiary or Jura-Cretaceous rocks may yet prove to be.

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*Dawson, G. M.—Geol. and Nat. Hist. Surv. of Can., Ann. Rep., Vol. III, 1887-88, p. 103B.

†McConnell, R. G.—Geol. and Nat. Hist. Surv. of Can., Ann. Rep., Vol. IV., 1888-89, pp. 31D, 46D, 37D.

‡McConnell, R. G.—Op. cit., pp. 45D-55D.

§See "Geological map showing coal areas in Alberta, Saskatchewan and Manitoba," by D. B. Dowling, Geol. Surv., Depart. of Mines, 1906, No. 1010.

Only a few areas are actually known to contain coal seams of economic importance, and some of these are so situated as to be of no present commercial value. Coal, to be workable under existing conditions in Yukon, must be situated on a railway or on navigable water.

The coal production in Yukon has been small, partly because there has been little demand for coal up to the present, and partly because only a few of the deposits are conveniently situated for shipping. The production for the past three years in tons was:

1910.	1911.	1912.
13,000	13,500	9,500

The amount of coal produced in the past, however, is no criterion as to what may be produced in the future. The following table gives the known and probable extent of coal-bearing formations in the areas already discovered in Yukon, and the probable amount of coal these beds contain. As mentioned before, however, Yukon territory is comparatively unknown, except along navigable waters, and, as might be expected, the accompanying map shows that the coal areas, at present known, practically all occur along the larger rivers. In compiling the figures given below, the possibilities of the extensive unexplored interstream areas, are not taken into account. The compilation, also, deals only with probable amounts of coal, for the reason that, on account of the undeveloped conditions of the seams, an estimate of coal actually in sight, would be misleading rather than informing. It is thought that the estimates given below are very conservative, and that probable amounts in the table, may almost be considered as equivalent to known amounts:

Extent of the known Tertiary beds in Yukon	2,090 sq. miles.
Extent of the known Jura-Cretaceous beds in Yukon	4,110 " "
Total	6,200 " "
Probable extent of Tertiary beds in Yukon	4,500 " "
Probable extent of Jura-Cretaceous beds in Yukon	19,700 " "
Total	24,200 " "
	Tons.
Probable amount of lignite in seams exceeding one foot in thickness in the Tertiary beds	3,135,000,000
Probable amount of lignite, bituminous coal and anthracite in seams exceeding one foot in thickness, in the Jura-Cretaceous beds	191,000,000
Total	3,326,000,000

THE DOMES OF NOVA SCOTIA.

By T. A. Rickard, London England.

(*Annual Meeting, Toronto,* 1912.)

Part I.

General Geology.

The Province of Nova Scotia is remarkable among regions yielding gold, not for the amount of precious metal produced, but for a beautiful lode-structure, the origin of which has provoked the constructive imagination of geologists for 50 years. As this interval of time coincides with the age of modern geology, the theories offered in explanation of local conditions serve admirably to illustrate the development of a science that has only lately achieved obvious economic importance as an aid to world-wide industry.

The gold mining region in question occupies the seaward half of the peninsula of Nova Scotia and is traversed by a series of sedimentary rocks into which granite has intruded. Mining in the granite has not been profitable, all the productive activities of the past having been confined to the sedimentary series, consisting of highly altered beds of quartzite and slate of great geologic antiquity, that is, at least as old as the Cambrian, although, in the absence of truthworthy fossil remains, it is uncertain whether they may not be even pre-Cambrian, namely, Algonkian. These beds of quartzite and slate have a known thickness of 30,000 ft., divided into an upper division of dark slate, with an estimated thickness of 11,500 ft., and a lower division of slate and quartzite about 18,000 ft. thick. It is in the lower series that the gold-bearing lodes are found, only one noteworthy mine having been worked in the upper slate, and even this exception occurs close to the line drawn between the two divisions.

The gold mining region has a maximum length, from east to west, of 200 miles, and a width, from north to south, varying

from 8 to 50 miles, so that the total area comprised is about 3,000 square miles (See map). The heart of the region extends from Caribou to Moose River, the horizontal distance being 10 miles and the vertical thickness of strata 18,000 ft., in one broad monoclinal fold with minor undulations. Across this section quartzite predominates, the slate appearing in beds relatively infrequent and thin. The sand-rock from which the quartzite originated must have contained lime, for calcite is abundant. The fine silt, now changed to slate, has been much hardened, but its true character is not obscured. Of later igneous rocks there is scant evidence, save at Tangier, where dikes of diorite have been noted; but they do not appear to have influenced the distribution of the gold. We have to deal, therefore, with metamorphosed sediments of one series and the granite that has intruded into and through them.

The age of the granite is important, for it bears upon the geologic antiquity of the ore despits. By reference to maps* it can be seen that the granite has displaced more than a third of the superficial area formerly occupied by the slate and quartzite formation; indeed, it has been suggested that the granite represents these rocks in the last phase of their metamorphism; but this is a deep question, in more senses than one, and need not concern us just now. As we see the granite to-day it is an intrusive rock, and therefore younger than the gold-bearing formation into which it has been thrust. How much younger? The evidence on this point is adequate: fragments of detrital granite are found in northern Nova Scotia within Middle Devonian sediments; on the other hand, in the Bear River basin the granite cuts into the Upper Silurian of the Oriskany horizon. Therefore the granite is older than the middle, and younger than the base of the Devonian; it is of early Devonian age. Between the deposition of the sediments now constituting the slate-quartzite series and the irruption of the granite, there stretches the whole of the Silurian period, and a part, if not all, of the Cambrian.

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*I refer to the excellent maps prepared by E. R. Faribault for the Geological Survey of Canada.

The slate-quartzite series is probably Algonkian; the granite is early Devonian; what, then, is the age of the gold-bearing quartz? The best answer to that is afforded by the fact that the quartz veins in places (as at Forest Hill) follow tongues or apophyses of granite, and gold has been detected in the granite at such places. Moreover, mineralized quartz penetrates the granite at other places (as at Country Harbour). Therefore the quartz is younger than the granite. Finally, a conglomerate known to be of Lower Carboniferous age and composed of the eroded fragments of the slate-quartzite series has been found at Gay's River, and from this conglomerate gold has been won by mining. The deposition of gold in the slate and quartzite must have commenced before the Carboniferous. Thus the gold and the granite do not differ widely as regards the time of their introduction, although the limits of one of the older geological divisions, such as the Devonian, include a period of time so vast as to beggar the imagination of a chemist in his laboratory. Nor is it to be assumed that the deposition of the gold, much less its distribution and concentration in the quartz, to constitute ore-bodies, was confined to any single period. Once brought within reach of the agencies of solution and precipitation lurking in the waters that circulate near the earth's surface, the gold became forever subject to migration, tending to be concentrated, concentrate or scattered the metal according to changing chemical and physical conditions.

The land now represented by Nova Scotia has passed through successive periods of pressure and uplift, the margin of the aboriginal American continent having been roughly parallel to the longer axis of the Province. The Algonkian beds have undergone tremendous folding. The Silurian and Devonian rocks overlying the gold-bearing series also exhibit plication, but the folds are not so conformable as to warrant the belief that one agency was responsible for all the disturbances recorded by these rocks of different geological ages. It is probable that the Algonkian sediments underwent lateral pressure throughout the Cambrian period and later, especially at the time of the granitic intrusion, for it is apparent that the basal strata from which the slate and quartzite were evolved have suffered long-continued

PROVINCE OF NOVA SCOTIA.

PROVINCE OF NOVA SCOTIA.

deformation. Besides the main folds, with their axes running east and west, there are cross-folds, the net result of which has been to form domes and troughs. These constitute the characteristic geological feature of the region and largely determine the shape of the orebodies from which gold is extracted by mining and milling.

The Domes.

The gold is associated with quartz, which in the main follows the bedding of the country-rock; hence it forms sheeted bodies of ore that are sandwiched between the strata, especially along the thin seams of slate. Since the quartz follows the structural lines of the country-rock, it forms 'saddles' where the slate and quartzite have been bent into anticlinal folds; but the most pronounced development of ore—for sometimes the quartz contains enough gold to constitute ore—is on the 'domes' formed where folds cross each other.

This domical structure leads to interesting results. Owing to erosion, the crests of the domes have been degraded to the level of the present surface, on the plane of which the bedding now assumes an elliptical form. Any vein of quartz deposited along a bedding-plane will reproduce this structure. If on a flank of the dome, north or south, it will have a nearly straight strike, but in the approach to the ends, east and west, of the dome, it will curve in accord with the fundamental structure. At the 'nose,' or extreme end of the longer axis of a dome, the quartz will be curved to a bow. All this is on the plane of the surface. If followed underground such a quartz vein will form a saddle, by being curved with the bedding of the anticlinal fold whose axis runs east and west. Again, owing to the synclinal fold, whose axis runs north and south, the saddle will pitch or slope if exposed at the east or west end of the dome, where the strata plunge in accord with the synclinal curvature of the cross-fold. This description will be made clearer by reference to the accompanying diagram, which, in effect, exhibits the appearance of a model if made in glass. The top of the block represents the geological surface; the elliptical outcrops are evident; at the west end of the curving strata are shown the quartz veins. These in

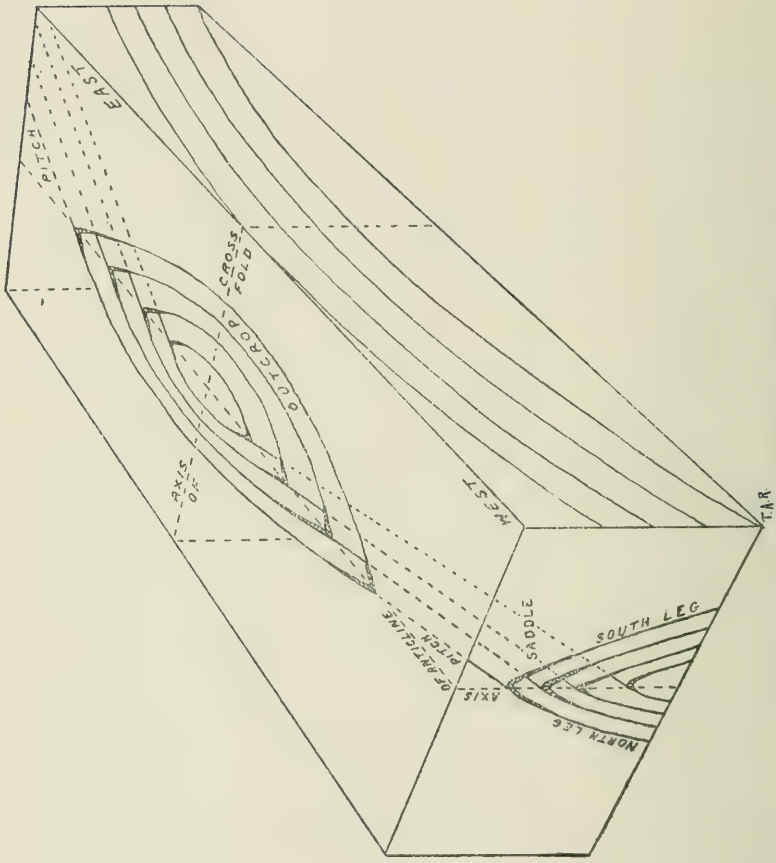


DIAGRAM OF A DOME

NOTE.—For "west" read "north," and for "east read "south."

cross-section, as exposed at the left side of the block, constitute 'saddles,' the pitch of which is indicated.

As regards actual mining, the workings that follow the pitching saddles usually consist of a sloping shaft with curving levels. This is best exemplified by the Richardson mine, a model of which was prepared by E. P. Brown.* At Bendigo, an Australian locality famous for this type of lode, the 'saddle-reef,' as it is there called, follows sharp arches in slate and sandstone, but the pitch of the anticlines is flat, because cross-folds are not emphasized; that is, the Bendigo saddle is like a steep ridge with slightly undulating crest. The Nova Scotian dome resembles the upturned bottom of a boat, the keel of which stands for the major anticlinal axis.

While referring to Bendigo as a geological analogy, a further reference may be made to the question of anticlinal pitch. In 1890 and 1891, when I was examining the Bendigo mines, the truly anticlinal structure of the 'saddle-reefs' was not recognized; hence the pitch of the anticlines was not considered. As the crests of the folds at Bendigo are not marked by violent changes of slope, especially within the short extent of a single mining property, it is not surprising that this detail of the local geology was neglected. Within recent years, however, it has become generally recognized that the changes of pitch or undulations along the anticlinal axis (there called 'lines of reef') constitute an important factor in modifying the distribution of gold-bearing quartz. Thus the Bendigo type of ore deposit finds closer resemblance to the Nova Scotian dome.

Only a small portion, however, of the gold contributed by Nova Scotia has been extracted from quartz at the apex of these domes. Most of it has been broken from interbedded veins associated with the legs or stumps of arched structures whose crests have vanished. It will be understood that the present surface, from which all mining starts, represents a nearly horizontal section that has been cut, by erosion, through the folds at a varying distance from their crests. The bedding-planes, and the quartz veins conforming to them, that are least curved, are

*Canadian Mining Journal, August, 1908.

simply farthest from the anticlinal crests, since all the beds of slate and quartzite are members of the folded series. The greater the distance from the anticlinal axis the less the curvature, so that many veins following the nearly straight strike and nearly vertical dip of the country appear to be unrelated to quartz deposits on the domes, although structurally they are allied. Such veins follow the lower portion of an arch, the crest of which, at a higher horizon, since denuded, overlapped the dome that survives in the centre of the fold. A distinction must be made, however; it is not necessary to assume, as some writers have done, that every quartz vein at one time extended over an arch of rock that has since been removed. That is another question. Whether the quartz was coterminous with the entire fold of the country-rock before it was reduced by erosion to the level of the present surface is a point on which I shall speak later. At present I am dealing with facts only, not theory. It is advisable to follow the scientific method of proceeding from the known to the unknown. It is not necessary to assume, and I do not believe, that the quartz vein distant from a dome, or an anticlinal arch, is a part of a much more extensive body that covered the crest of a dome eroded long ago, nor that the interbedded quartz now found several thousand feet from any anticlinal axis was contemporaneous in its origin with, however dependent in structure upon, the lines of weakness created in the rock formation during the process of folding.

At the Dufferin mine, in the Salmon River district, I saw a dome whose outcrop is barely 2,000 ft. long, east to west. In other districts such as Caribou, Mount Uniacke, and Oldham, it is obvious, from the geological surveys of Mr. Faribault, that domes exist having a length of 2,500, 2,000 and 3,000 ft., respectively. Quartz, in the shape of saddle-veins, has been concentrated at the cross-folds, where the nose of the dome plunges underground, but in no case, as far as I know, has it been exploited profitably at both ends of a dome. In the Dufferin the domical structure is exposed on the 300-ft. level, which follows a quartz vein known as the No. 1A. Here, as shown in Fig. A, the east and west legs of the dome are 1,300 ft. apart, while the north and south legs have a spread of only 200 ft. at

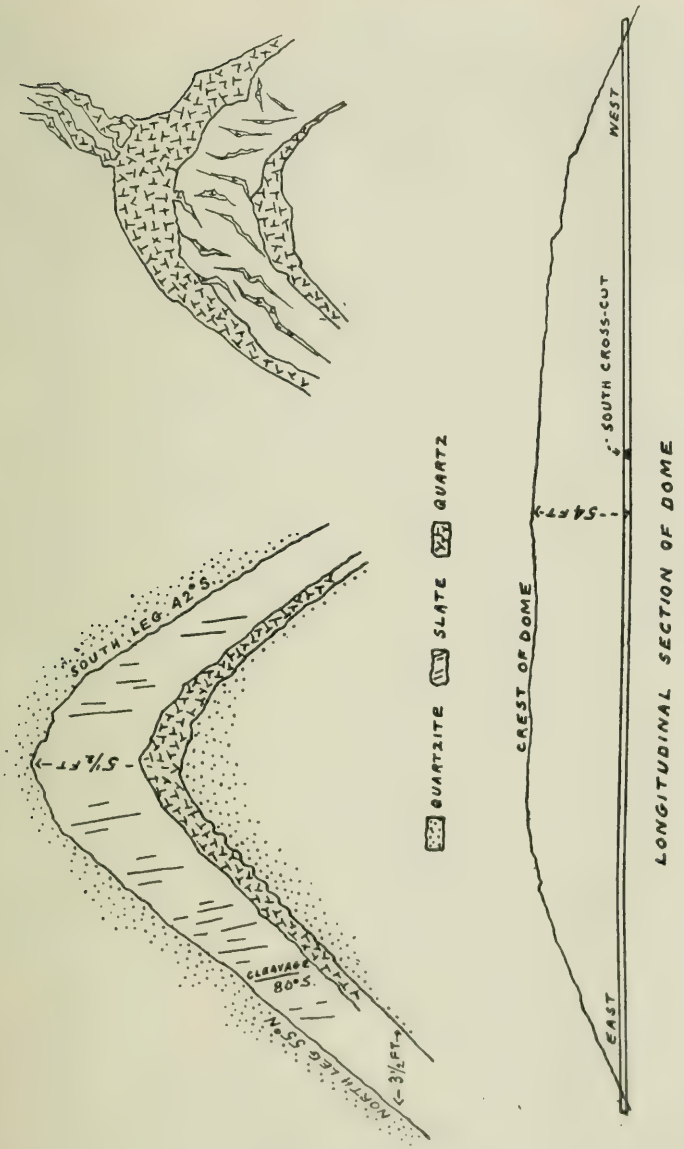

SOUTH LEG 42°S.
NORTH LEG 55°N.
CLEAVAGE 80°S.
QUARTZITE
SLATE
QUARTZ
CREST OF DOME
EAST
WEST
SOUTH CROSS-CUT
LONGITUDINAL SECTION OF DOME

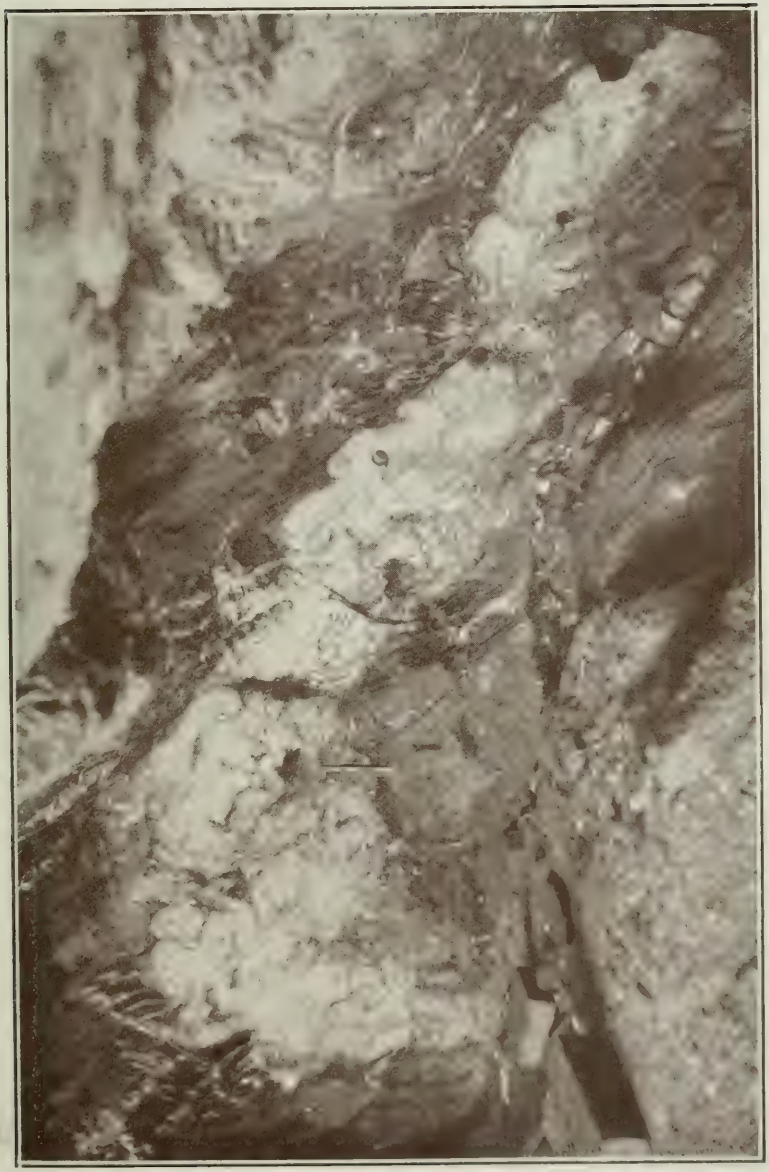
FIG. A.

the same level. Since Mr. Faribault's map was published, it has been ascertained by him that the anticlinal fold is not a single flexure, but divided into two saddles at its crest. Of these, the southern is accompanied by a succession of quartz saddles, which have been exploited to a vertical depth of 300 ft. and then abandoned as unprofitable. The northern minor flexure has no saddle of quartz, but its northern leg is accompanied by a band of quartz stringers that extend as cross-veins from the apex to the surface and reach in depth to the point where the bedding is turned by the syncline. Stringers of quartz cross the veins that follow the bedding, and it is suggested that the former coincide with fractures due to the cross-fold. In 'centre country,' that is, at the axis of a fold, even the quartzite exhibits cleavage. As regards the saddles, it is apparent (in Fig. A) that the anticlinal axis is not vertical, but dips south; hence the south leg is flatter than the north (See also Photo No. I.). The cleavage is at a high angle southward. The north leg has been more profitably mined than the south, because the latter is terminated abruptly by the synclinal flexure. The corrugation shown under the north leg of the larger saddle near its apex conforms to the pitch of the anticline, which is 2° W. at 125 ft. west of the shaft. The saddle shown on the left of Fig. A. is a supplementary saddle below the main formation exploited in the Dufferin mine. The quartz is from 8 to 10 inches thick at the apex, and thins going down. The right-hand sketch shows how stringers extend from the saddle across the bedding, but in the line of the anticlinal axis.

From 1881 to 1895 the Dufferin mine yielded 39,130 oz. gold from 93,701 tons, showing an average of 8 dwt. per ton.

CRENULATION.

The 'saddles' of Nova Scotia are also remarkable for peculiar corrugations or crumplings of quartz, to which the name of 'barrel formation' has been accorded, because, when such a corrugated deposit is uncovered, it looks to the miner like the back or top of barrels lying in rows. The accompanying reprints (See p. 431) from old woodcuts, appearing in a report by Silli-



No. 1.—A saddle lode in the Dufferin mine.

No. 2.—The Dunbrack vein at Oldham.

man, will indicate the appearance of such a lode as exposed in a large open-cut on the crest of a hill at Waverley.* I went thither in August, 1905, and saw enough to confirm the general accuracy of these sketches. The corrugation, crinkling, or crumpling, as it has been variously termed, was most remarkable. As a technical term descriptive of this structure, I suggest 'crenation' from *crena,* a furrow or notch, for the larger barrel structure, and 'crenulation,'† from *crenula,* the diminutive of *crena,* for the smaller apparently serpentine threads of quartz.

While adopting the Latin derivative for the barrel structure, I deem it best to use the English word, 'furrow,' for the individual markings that constitute the appearance termed 'crenulation.' For the larger manifestation of the same structure it might, from an academic point of view, be desirable to use 'crenation,' but this is not necessary to a clear description, and may, therefore, be set aside for the present. 'Furrow' and 'crenulation' apply to the markings in the wall-rock, and not to the quartz filling them. The quartz is found in veins of varying continuity, and in shape reproducing the structure of the encasing rock. Hence it appears crinkled, corrugated, crumpled, or serpentine, according to the degree to which the angles are curved. When enlarged, the bends make the so-called 'barrels'; when infrequent or individual, and especially when persistent, the 'barrel' becomes known as a 'roll.' Though varying in size and multiplicity, these forms of gold-bearing quartz are the product of similar structural relations.

The famous ore deposit of Waverley lies at the crest of a low hill, and at the western end of it, where an anticline is crossed by a syncline, so as to cause the folded strata to pitch steeper than the gentle hillslope. The accompanying map and section (Fig. B and Fig. C) are cut out of the larger map made by E. R. Faribault for the Geological Survey of Canada. They illustrate

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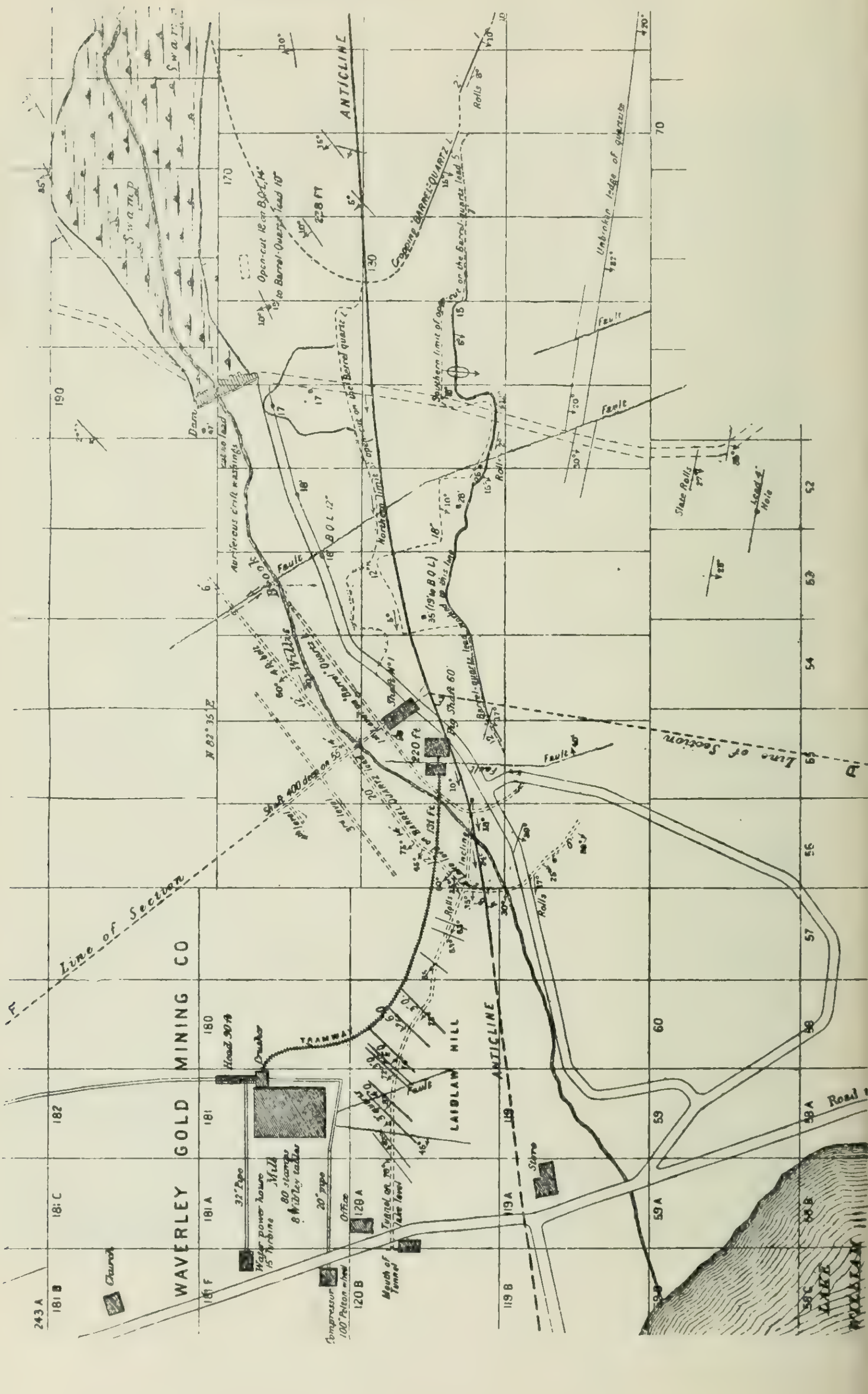
*It is sometimes spelled Waverly. I have adopted the spelling used by the Canadian Geological Survey.

†This term has been previously used by J. Edmund Woodman, in his paper on the "Geology of Moose River Gold District"; Nova Scotian Institute of Science, 1903, vol. xi., part I., pp. 18-88.


WAVERLEY GOLD MINING CO
LAIDLAW HILL
ANTICLINE
ANTICLINE
Line of Section
Line of Section
Swamp
Swamp
TRAMWAY
Mill
80 stamps
Church
Office
Store
Fault
Fault
Fault
Dam
Road
Unbroken ledge of quartzite
Cropping 'BARREL-QUARTZ'
N 83° 35' E

CROSS-SECTION ON LINE DEF.

the excellence of his topographical and geographical surveys. The following description is transcribed from my notes made on August 18, 1905. On the crest of the hill the apex of the pitching saddle is uncovered by shallow diggings; the quartz has been removed, but Silliman's sketch indicates how it looked when stripped. In the old excavations, which followed the north and south legs for a few feet, the crenulation on the hanging-wall quartzite can be seen. The furrows are nearly horizontal, or at right angles to the dip of the wall-rock. On descending the incline-shaft of the mine to the third level, the crenulation is found pitching at a strong angle with the dip of the stratification, becoming steeper in the approach to the main anticlinal

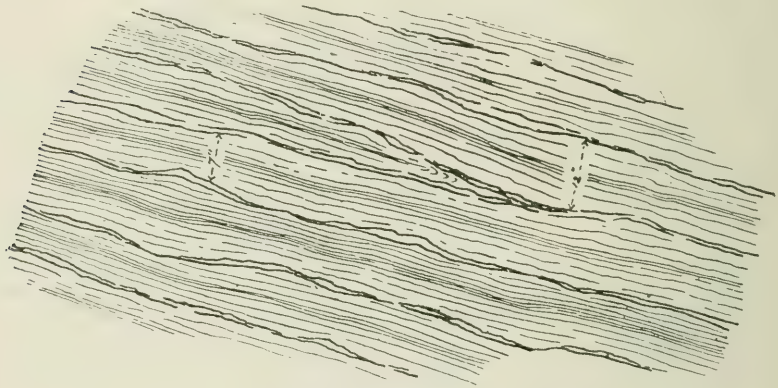


FIG. D.—Furrowed foot-wall at Waverley.

axis. On this level the slate of the foot-wall shows where the crenulated quartz formerly lay, leaving casts like those left in river mud by logs, of irregular length and width, placed alongside. It is not an undulation; it is a furrow (See Fig. D.) The quartz remaining averages 8 in. thick, with a maximum width of 12 to 15 inches. The vein crosses from the foot-to the hanging-wall of the slate bed within a distance of 20 to 25 feet. The slate is not faulted. Numerous joints cross the fluting and cause it to resemble bamboo. The cleavage and the bedding intersect along the line of the crenulation. On the south side of the anticline the furrows plunge eastward, until on reaching the anticlinal

axis (near the Pig shaft) they are parallel to it; here, therefore, they conform to the dip but are at right angles to the strike of the vein and its enclosing wall-rock. As the vein curves at the nose of the dome and is followed around the corner, so to speak, the crenulation begins to exhibit a deviation from the dip until it is again pitching at a decided angle. At a point 125 feet eastward from the Pig shaft the quartz has diminished to a seam

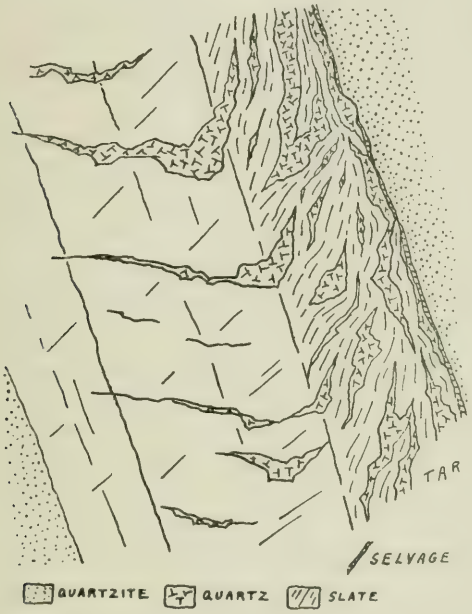


FIG. E.—The Lode at Waverley.

only 2 or 3 inches thick; concurrently the slate has dwindled from a bed 7 or 8 feet thick (at the apex) to a few inches, and the crenulation has faded away. When last visible it was nearly horizontal, that is, at right angles to the dip of the wall-rock. On the intermediate level the cleavage is seen to be opposed to the bedding. There is a suggestion of radiated fracturing or fissility. The accompanying sketch (Fig. E) shows the lode on the No. 1 level looking west at the north leg. Thus at Waverley the crenulations or barrels pitch with the anticline at the axis

and flatten as distance is gained along the flanks of the dome. At 400 ft. from the axis the furrows lie at an angle of 8° from the horizontal, and shortly before becoming horizontal they disappear.

The total yield of the Waverley district (up to the cessation of work in 1898) is 61,308 oz. gold from 122,346 tons of ore, this being an average of 9½ dwt. per ton.

As a persistent advocate of the precise use of technical terms in descriptive writing, I cannot refrain from remarking on the fact that the maps of the Geological Survey employ the word 'dip' to indicate the angle of the rolls and of the crenulation, when reference is obviously meant to the 'pitch.' The 'dip' of the slate is given, say, as 52° W., and then the 'dip' of the crenulation is given as 15° N., when, of course, the crenulation is on the plane of the slate bed, and therefore dipping the same, but pitching north at a strong angle. 'Dip' is measured at right angles to the strike; 'pitch' is measured along the strike. Again, the use of 'whin' to signify quartzite, is bewildering to anyone who is not familiar with the local Nova Scotian usage; for 'whin' has heretofore been applied, also locally, in Derbyshire, to an igneous rock. Hardly less objectionable is the local term 'belt' for slate, because this is commonly used in another sense in geology. Thus, one author speaks of a 'belt' of angulars; one might infer that it was a bed of slate full of cross-veins; and when it is written that "the belt follows the stratification," one concludes—at least I concluded for a moment—that a geologic truism was being stated. Another objectionable localism is 'pay-streak' to signify ore-shoot; in mining a 'streak' is a thin prolongation of ore, a thread-like or ribbony structure, but in Nova Scotia it refers to an orebody having a definite pitch. While only clumsy and unnecessary when employed locally, such terms are undoubtedly confusing and misleading when used in writings intended to be read by persons at a distance.

At Oldham more evidence was gathered. Here the mining was at the eastern end of a dome. In an excavation at the side of the road I made the sketch shown in Fig. F. The bedding dips 45° S.; the cleavage is 62° N. The line of intersection pitches

clearly at 12° E. The crenulation pitches similarly. In approaching the nose of the dome, or the place where the anticline is crossed by a syncline, it is apparent that the furrows and the quartz associated with them pitch eastward at an increasing angle.

Oldham is celebrated for its 'rolls.' These I regard as isolated or infrequent furrows of larger amplitude. Thus a 'roll' in a quartz vein, following the bedding-plane, represents a persistent enlargement and enrichment along a bend in the

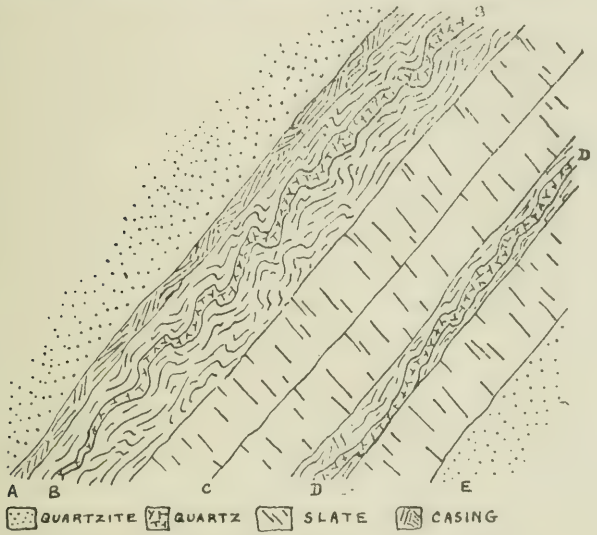


FIG. F.

foot-wall. A roll is sometimes found where a cross-vein or 'angular' meets a vein that follows the bedding. This would appear to mark a displacement at the intersection, just as the normal roll represents a slip where the cleavage crosses the bedding. Angulars are most plentiful at the place of cross-folding, that is, where intensity of movement has induced maximum fracturing.

Oldham has been able to boast some small rich mines. Most of them have yielded gold from recognized rolls, to which the names of their discoverers still cling. One of the most famous is the Hardman roll, named after that veteran engineer, John E.

Hardman. This roll is on the Dunbrack vein, which dips 38° S. near the surface and increases (at a depth of 300 ft. vertically) to 46°. Two rolls, parallel to each other, have been found. The first, or Ned's roll, carried 6 to 8 inches of quartz in an ellipsoidal body 10 to 15 feet long. The second, or Hardman roll, carried 10 to 15 inches of quartz, increasing rarely to 18 in., and for a length of 18 ft., narrowing at one place to 8 ft., but fairly uniform in size. Both rolls are accompanied by minor fluting of the foot-wall. In going eastward this crenulation, with the rolls, pitches more steeply. Between the rolls the wall-rock exhibits sharp fluting and is accompanied by 4 to 5 inches of quartz. The first roll was struck in the No. 2 shaft at 160 ft. and the second at 300 ft. on the dip. The No. 1 shaft cut the first at 300 ft. and the second at 450 ft. on the dip. It appears, therefore, that they maintained an approximate parallelism. Eastward these rolls are cut off by a well-defined fault; they have not been exploited beyond it, although the geological map indicates the position of the vein east of the fault. It is stated that the top roll marks the junction with an angular. These are notes obtained from Messrs. E. R. Faribault and D'Arcy Weatherbe, with data given by resident miners. The workings are no longer accessible.

On writing to Mr. Hardman, in November, 1905, he stated to me that the rolls are "simply enlargements of the quartz vein-filling, horizontal sections of which have the form of elongated ellipses." The quartz of the Dunbrack vein, he added, had a general assay-value of $3 to $15 (or 3 to 15 dwt.) per ton in free gold, whereas the ore of the roll itself never yielded less than $25, and sometimes as high as $1,600 per ton "for lots of 8 to 10 tons." The high-grade ore was associated with galena and zinc-blende, the poorer quartz carrying from 1½ to 2½% mispickel, iron pyrite, and pyrrhotite, all of these minerals being found also in the rich ore, but subordinate to the galena and blende. Mr. Hardman says:

"The thickness of the Dunbrack vein as a whole (throughout its worked extent of over 2000 ft.) would range from 4 to 5 in.; in places it narrows down to an inch or less, in other places it widens out to about 9 in., but the average width, apart from the rolls, I should put at about 5 inches. In the rolls this width is much increased, the average width of

the quartz in a roll being about 17 to 18 inches. The extremes within the rolls would run from 8 to 22 inches. Occasionally there came into the vein what are called 'angulars,' which you will recognize under the more general name of 'feeders.' These are small quartz-veins, of very limited length, and comparatively limited width (ranging from ½ in. to 1½ in.); often they are pure quartz, but also often they contain quite an amount of carbonate of iron or siderite. These angulars, when coming into the vein from the quartzite hanging-wall had little or no effect on the richness of the ore, but when they came in from the foot-wall side, also through the quartzite, they were decided feeders or enlargers of the quartz above them."

I append a photograph (No. 2) given to me by Mr. Hardman, but taken by Mr. Faribault. I also add a photograph (No. 3) of the furrowed foot-wall of the Sterling vein, at Oldham, as seen near the bottom of a 35° incline on the eastern nose of a dome. The incline had followed the quartz, here removed, for 725 ft. on the incline or pitch of the anticlinal fold.

At Mount Uniacke, on August 21, 1905, I saw a 'crumple' or subordinate fold in the Borden vein. This was described by Mr. Faribault in the summary report of the Canadian Geological Survey for 1903, and is there accompanied by a beautiful explanatory drawing. The evidence obtained in the course of mining indicates that the subordinate fold is echoed by a series of strata, and that the quartz veins following the fold are connected by stringers along the anticlinal axis. The workings visited by me showed that the fold had an amplitude or cross-sectional measurement of 40 ft., and a height or vertical measurement of 15 ft. It had been followed for 340 ft. on the pitch, which sloped eastward at 15°. This small fold showed a double crumple in the roof or hanging-wall and a single bend in the foot-wall, the divergence into the two crumples being accentuated eastward. Here we have, on a small scale, a maximum of contortion in the bedding, creating highly favourable conditions for the passage of mineral solutions. This locality is 650 ft. south of the main anticlinal axis, and at the westward end of a dome.

The accompanying sketches and photographs will illustrate the structure. First come Mr. Faribault's drawings. Fig. G is a general cross-section, showing the relation of a series of parallel veins, and the subordinate fold as exposed in four successive 'leads' or veins. Fig. H is a detailed section on the Borden vein. It will be noted that he marks the cleavage in the slate as

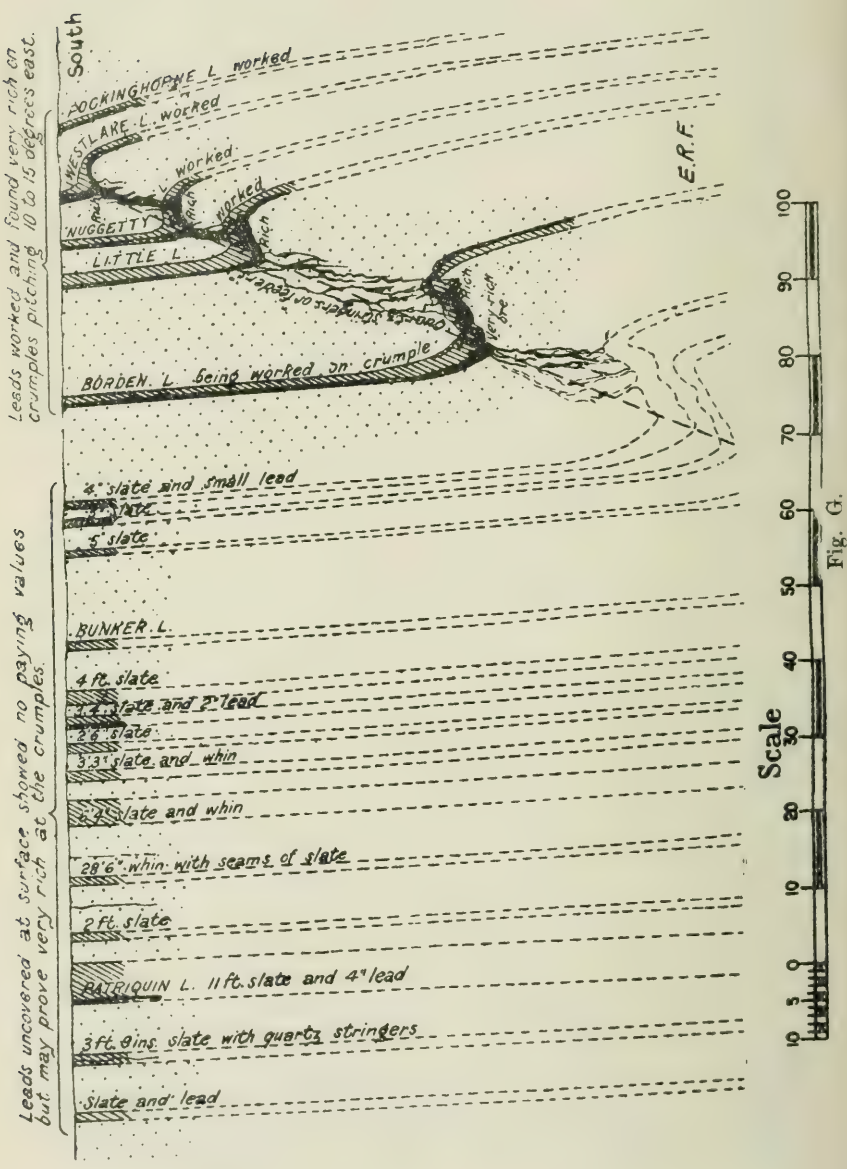

South
ROCKINGHORNE L. worked
WESTLAKE L. worked
NUGGETTY
worked
LITTLE L.
worked
BORDEN L. being worked on crumple
E.R.F.
Leads worked and found very rich on crumples pitching 10 to 15 degrees east.
4' slate and small lead
5' slate
BUNKER L.
4 ft. slate
2'6" slate
3'3" slate and whin
2'4" slate and whin
28'6" whin with seams of slate
2 ft. slate
PATRIQUIN L. 11 ft. slate and 4" lead
3 ft. 9 ins. slate with quartz stringers
slate and lead
Leads uncovered at surface showed no paying values but may prove very rich at the crumples.
Scale
100
90
80
70
60
50
40
30
20
10
0
5
10

Fig. G.

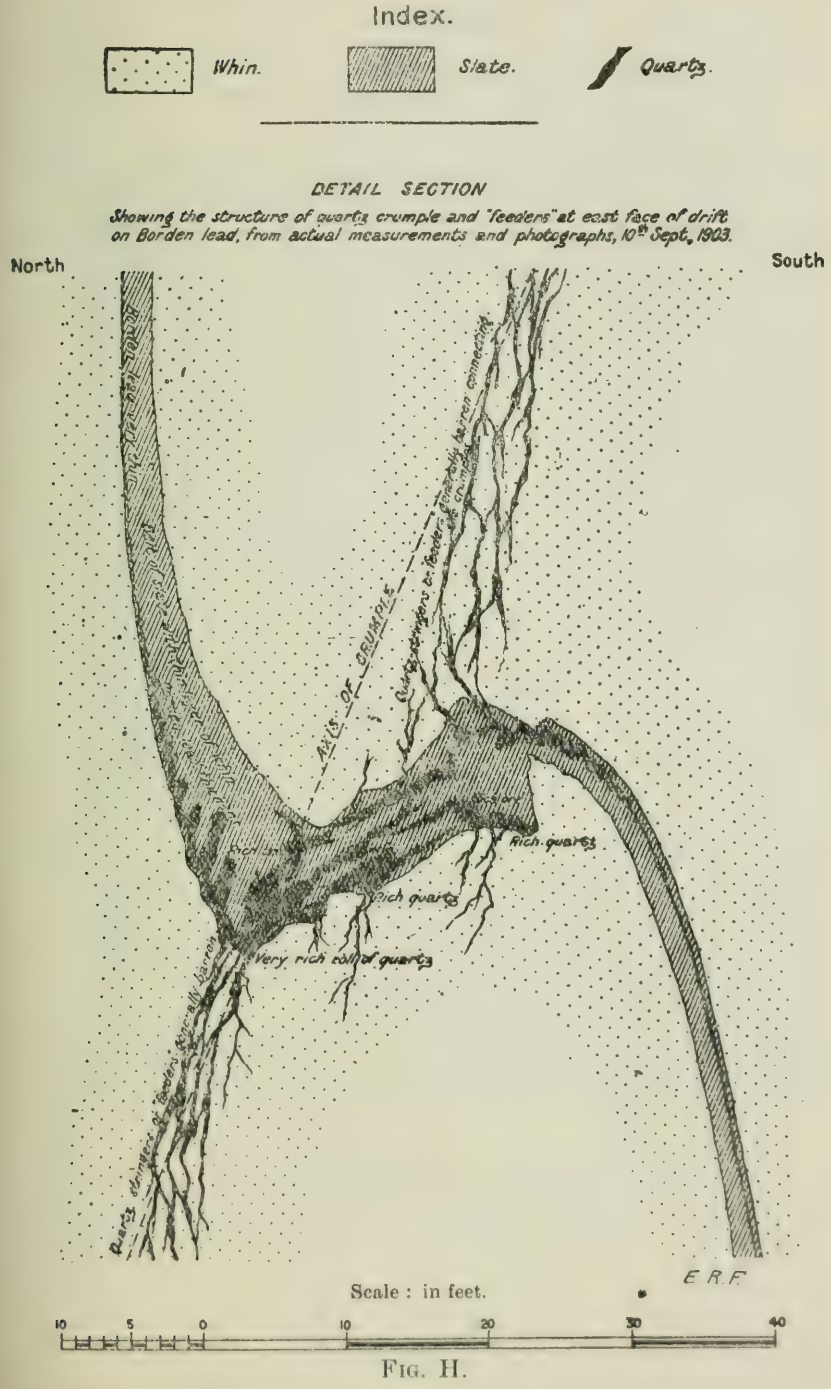

Index.
Whin.
Slate.
Quartz.
DETAIL SECTION
Showing the structure of quartz crumple and "feeders" at east face of drift on Borden lead, from actual measurements and photographs, 10th Sept., 1903.
North
South
Axis of crumple
Rich quartz
Rich quartz
Very rich coil of quartz
E R F
Scale : in feet.
10
5
0
10
20
30
40

FIG. H.

being at a high angle northward. Fig. I is a sketch made by me in an old stope. A quartz stringer along the anticlinal axis indicates the system of feeders connecting the successive crumples. The crenulation accompanying the quartz, previously removed by mining, is seen in an adjoining shaft, where it slopes west slightly; in an open-cut farther west the 'fluting' or crenulation pitches 4° to 5° eastward owing to a local bend in the strike of the slate bed. The crumpling or subordinate fold, of course, will not be confused with the crenulation; one is a local plication of the bedding-planes, while the other is a fluting along the sur-

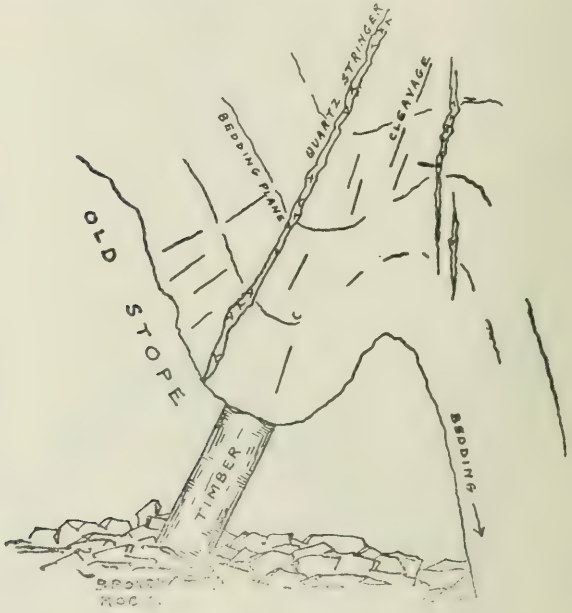
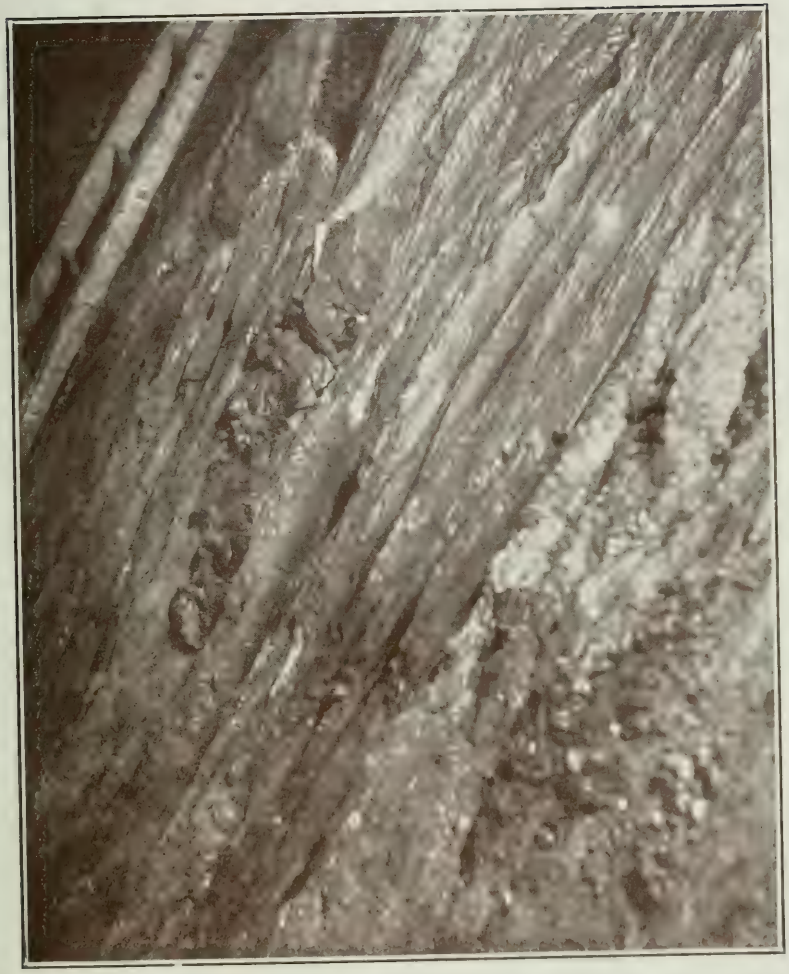
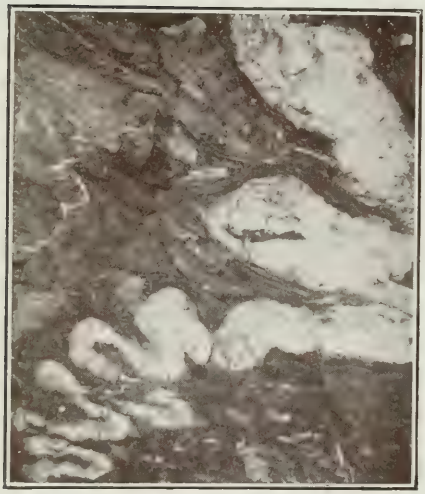


FIG. I.

face of the beds. On the bottom level of the mine the cleavage is distinguishable in the quartzitic rock of the foot-wall, and it is seen that the line of intersection with the bedding pitches 15° to 20° west, while the incipient crumpling on the same wall-rock pitches 10° to 15° east. Fig. J is a sketch taken in a stope on the south leg of the crumple and 150 ft. east of the shaft. The crenulated quartz vein is nearly in the centre of a bed of slate (2 ft.



No. 3.—Crenulated foot-wall of the Sterling vein at Oldham, as seen after the quartz has been removed.



No. 5.

No. 4.

thick), but it does not follow the bedding. The cleavage is almost at right angles to the walls of the slate bed, the foot-wall of which is followed by a vein of 'bull' quartz, namely, barren white quartz as distinguished from the bluish-grey mineralized quartz of the crenulated vein. The latter shows occasional banding, due to included slate. This is a good example of the 'barrel' quartz of Nova Scotia.

The accompanying photographs (Nos. 4, 5, 6, 7, and 8) will illustrate the extraordinary character of the crenulation. The photographs were taken by D'Arcy Weatherbe and E. R. Faribault, who were deputed to be my assistants when making the

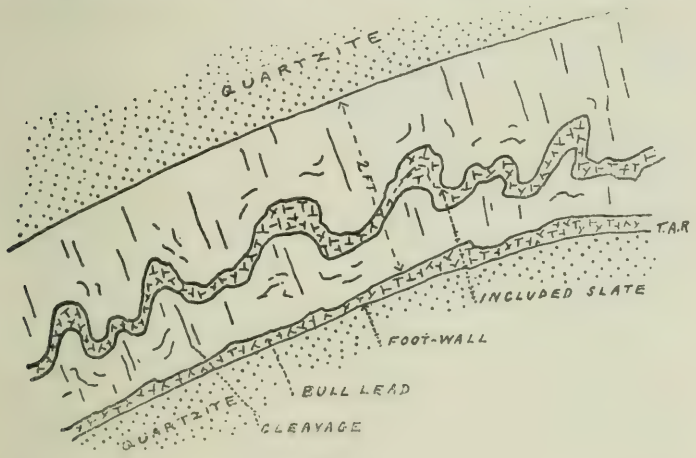


Fig. J.

geological investigation for the Government. No. 4 and No. 5 show the crenulation impinging on the 'roll' formed by the crumple or minor fold. No. 6 exhibits a small fault. The crenulated quartz vein overlies a 'bull lead,' that is, a barren quartz vein, which follows the bedding-plane. The crenulated or 'barrel' vein is in a bed of slate. No. 7 is another of the same vein, the Borden 'lead,' at Mount Uniacke. No. 8 again exhibits this remarkable ore deposit; for the quartz is gold-bearing and was being stoped profitably at the time of my visit. No. 9 exhibits the structure even better. The crenulated vein is accompanied by a simple quartz seam, marking the bedding-plane

between the slate, in which the crenulated vein lies, and the quartzite of the foot-wall. No. 10 shows the crenulated foot-wall of the Murray vein at Mount Uniacke. The crenulation pitches 75° E. No. 11 illustrates the same structure on a larger scale. It is similar to that shown in No. 10. Additional examples appear in No. 12, 13, 14, 15, and 16. The first of these (No. 12) is a fine photograph, by Mr. Faribault, of the Serpent vein in the Moose River district. The scale is about 1 foot to 1 inch. No. 13 represents a 'small curly lead' in the Mexican mine at Goldenville. The bedding—diagonally across the crenulated vein—is clearly indicated by another quartz vein. No. 14 shows the Touquoy vein, in the Moose River district. The cleavage of the slate is indicated above the quartz vein. No. 15 illustrates a quartz vein zigzagging across the bedding-planes at Forest Hill. No. 16 is a photograph of two crenulated veins at Moose River. The scale is indicated by the hammer and the Canadian $5 bill. This photograph shows two nearly symmetrical veins, but they are not conformable. In Photograph No. 18 the Great North vein at Moose River is shown. Here the relation of the crenulated vein to the cleavage and the bedding is evident. No. 19 shows the workings on the Taylor vein, also in the Moose River district, on the south anticline, with a minor synclinal fold. The cleavage of the slate is evident. No. 20 shows a subordinate syncline in the Montreal Co.'s quarry at Moose River. The cleavage is evident. Several of these photographs appear in Mr. Woodman's paper on the district, and to him I am indebted for many of my prints. No. 21 shows a thick bed of quartzitic rock overlying the Cameron vein at Ecum Secum. The cleavage and jointing are evident. No. 22 is a photograph of the Richardson vein, where it is evidently crossed by quartz stringers of later origin. No. 23 is a series of veins in the Beaver Hat mine, at Isaac's Harbour. These veins are at a crumple or subsidiary fold in quartzite at a depth of 40 ft. from surface.

ORIGIN OF THE CRENULATION.

The origin of this beautiful structure is difficult to explain. The first idea, adopted by some of the early observers, is that the quartz constitutes an integral member of the sedimentary series,

No. 18.- A crenulated vein traversing the bedding.

No. 9.—The Borden vein in the West Lake mine at Mount Uniacke.

that is, the silica that became quartz was deposited contemporaneously with the silt and sand that became slate and quartzite. According to this theory, the quartz underwent folding and corrugation with the encasing rock, and was particularly plicated at the places where anticlinal movements crossed. This simple explanation is killed by the single fact that the crenulated veins cut across the bedding-planes between the slate and quartzite (See photographs No. 9, 13, 15, and 18).

The next theory that may be proffered is that the quartz has replaced another mineral, segregated from the original sediment and distributed along bedding-planes or other lines affording passage to underground solutions. Calcite is prevalent throughout the region, and in association with the quartz; therefore it may have occupied the fractures in which quartz is now found. Such calcite would have been crushed by the earth-movements and thus it would be all the more easily soluble in silicious acid waters. This theory also lacks the support of evidence. It is true that although we cannot conceive a layer of quartz undergoing violent bending without becoming crushed, a condition in which quartz is not uncommonly found in lodes,* we can imagine more readily that calcite could better withstand the strain, and even if crushed it might, at a later period, be replaced by quartz. In this connection we may remind ourselves, on the testimony of natural sections, that rock deformation ensues in the deeper portion of the earth's crust. C. R. Van Hise has estimated that at 12,000 metres "the weight of the superincumbent mass is greater than the ultimate strength of the rocks,† which then undergo 'flowage' or deformation without fraction." These considerations might well apply to the case in point, for, as we have seen, the rocks encasing the gold-bearing quartz now being mined in Nova Scotia were at one time covered by eight miles, or 42,000 ft., of superincumbent strata. Moreover, the practical researches of Frank D. Adams, in the laboratory of McGill University, prove that many rocks and minerals are capable of deformation without rupture when under great pressure.‡ Thus we have

*Such as the Comstock.

†*Trans. Amer. Inst. Min. Eng.*, vol. xxx., p. 32.

‡*The Journal of Geology*, vol. xviii, No. 6. 'An experimental investigation into the action of differential pressure on certain minerals and rocks.' By Frank D. Adams.

evidence on this point; but it is not applicable to our problem. If it be supposed that the quartz replaced another mineral which was deposited along the bedding planes, either by original sedimentation or by subsequent segregation, we are again faced by the fact that the crenulated veins cross the planes of bedding. Hence they could not so originate. If we recognize that the quartz does not lie wholly along the planes of bedding, then the problem of explaining the crenulated structure is not facilitated by imagining quartz to have replaced calcite, for any explanation that would suffice for one would be adequate for the other. Therefore this second theory does not carry us any further forward. We dismiss it, with regret.

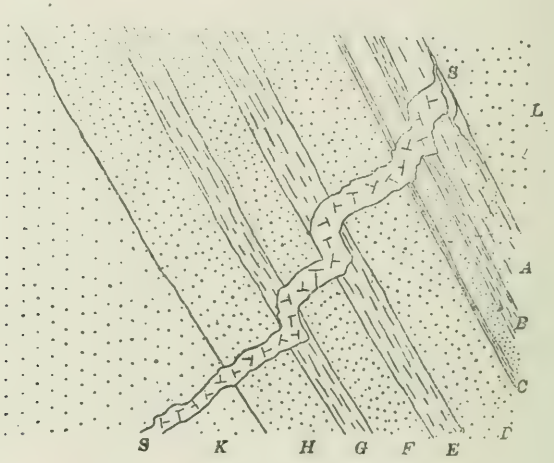


FIG. K.

The next theory is not so easily stated, but it is based on the observation that quartz veins exhibit a step-like or zigzag course in traversing beds of diverse texture and in crossing the cleavage, joints, or other structural inequalities of a homogeneous rock. Thus, at Bendigo, I noticed that the 'spurs' or cross-veins, which are mined profitably on a large scale, have a marked characteristic: they cross the sandstone almost at right angles to the bedding, but they tend to follow the cleavage of the slate. See Fig. 5, 9, 10, 11, 13, 14, 30, 31, 33, and 34 of my paper en-

titled "The Bendigo Goldfield" (second paper), *Trans. A.I.M.E.*, vol. xxi., pp. 686-713. Fig. K reproduces Fig. 31 of my Bendigo paper. On turning to the description, written in 1892, I find that I referred (on p. 688) to this characteristic in the following words: "A quartz seam upon leaving a bed of sandstone and entering one of slate, invariably turns its dip in sympathy with the cleavage of the slate." To put it in another way: a fracture crossing a series of slate and sandstone (or quartzite) beds will cut right across the sandstone because it is of fairly uniform texture, so that it is as easily broken one way as another. The same fracture, when encountering a fissile rock, like slate, will find the path of least resistance along the cleavage rather than across it. Hence the fracture, in crossing an alternation of such rocks, will take a step-like or zigzag course. (See Fig. L).

If, now, the beds be thin we find this structure emphasized. (See Fig. M).

If, next, we suppose the alternation to be repeated with greater frequency—if, in other words, we take a shaley sandstone marked by well-developed cleavage—we obtain conditions favourable to a crinkly line of fracture. (See Fig. N).

This affords a clue, which appears to be confirmed by the significant fact that the crenulation, as seen in the Nova Scotian mines, has a pitch conforming to the line of intersection between the bedding and the cleavage. It appears to be dependent on a relation to the cleavage.

Crenulation is not unknown at Bendigo, although there it is not a dominant characteristic. On turning to my first paper on the Bendigo goldfield (*Trans. A.I.M.E.*, vol. xx.) I find two sketches, Figs. 65 and 66, illustrating this structure. Fig. O reproduces the Fig. 65 just mentioned; it is particularly interesting because it shows that the deposition of quartz has followed not only the lines sympathetic to the bedding but also a nearly vertical fracture along the anticlinal axis, as well as another that shows some kinship to cleavage. We must remember that the shape of the quartz is determined by the nature of the receptacle that it occupies; even if we suppose it to have found room by replacing portions of the country-rock, we have to ascer-

tain the nature and shape of the fractures along which it found a way when in solution. Veins of quartz vary in dimension and direction in accordance with the diverse texture and hardness of the rocks traversed by fractures precedent to ore deposition.

These fractures are various. The lines of weakness along the bedding-planes, especially such as separate a relatively soft from a relatively hard rock, a slate from a quartzite, for example, furnish obvious facility for rupture. Along these is deposited the quartz of the ordinary saddle-vein. Other things being equal, the crest of an anticline furnishes an opening or a tendency to open; the syncline does this also, but, while the principle of the arch tends to keep the anticlinal fracture open, the dead weight of a trough-like depression or syncline tends to close it. Between the two bends, on the flanks of the anticline—which are also the reversed flanks of the syncline—the strata are compressed, the bedding-planes are tight, and the least possible facility is afforded for the circulation of underground waters. Connection between the crests of the anticlines is obtained by fractures that follow the anticlinal axis, as in Nova Scotia, or by dikes that have been injected in the wake of regional dislocation, as at Bendigo.

In a region marked by folding, the greatest intensity of fracturing is exhibited at the place of maximum plication. At Bendigo this is found at the apex of an anticline. In Nova Scotia it is found where the folds intersect, that is, where an anticline plunges in obedience to a transverse syncline: at the nose of a dome. It is there that the crenulation is most marked. Folding is accompanied by cleavage in fissile rocks and by jointing in those of granular texture. The main anticlinal axes are charac terized by a dominant cleavage, usually at a high and persistent angle. At the approach to the apex of the fold, and more especially at the place where the rock is twisted by cross-folds, the regional cleavage is dominated by a local radial fissility, exemplified in several of the annexed photographs. It is there that the crenulation is most marked and most continuous.

At the place of maximum flexure, where the cleavage dominates the bedding, any fracture due to regional movement will find a devious way. In part it follows the bedding or, at least,

No. 10.—Crenulated foot-wall in open-cut at Mount Uniacke.

No. 11.—Crenulated foot-wall at Mount Uniacke.

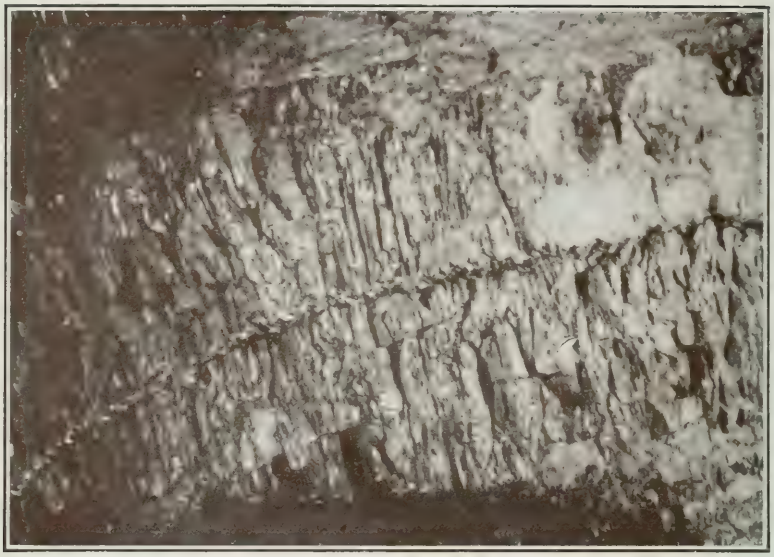
No. 12.—The Serpent vein at Moose River. Scale: 1 inch=1 foot.

No. 13.—In the Mexican mine at Goldenville.

No. 14.—The Touquoy vein at Moose River.

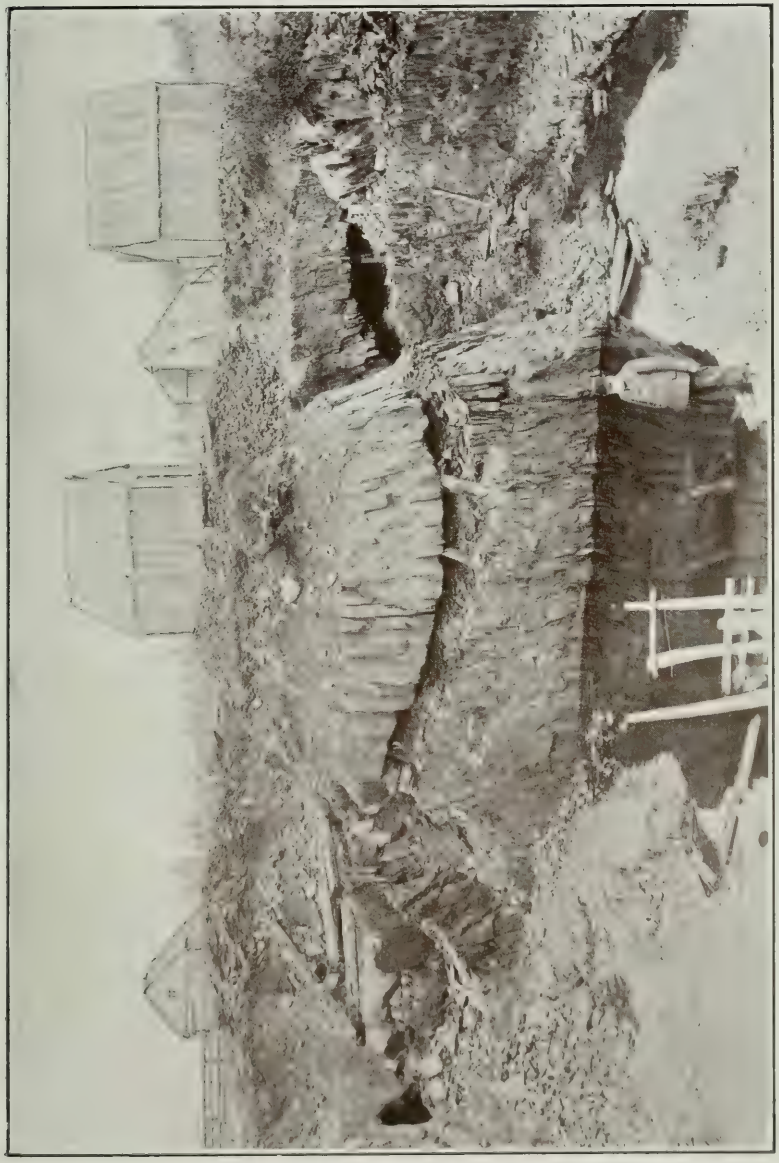
No. 15.—Quartz stringer cutting across the bedding-planes.

No. 16.—A couple of crenulated veins at Moose River.



No. 20.—The Great North vein at Moose River.
This crenulated vein is shown as a serpentine thread in the midst of a bed of slate.

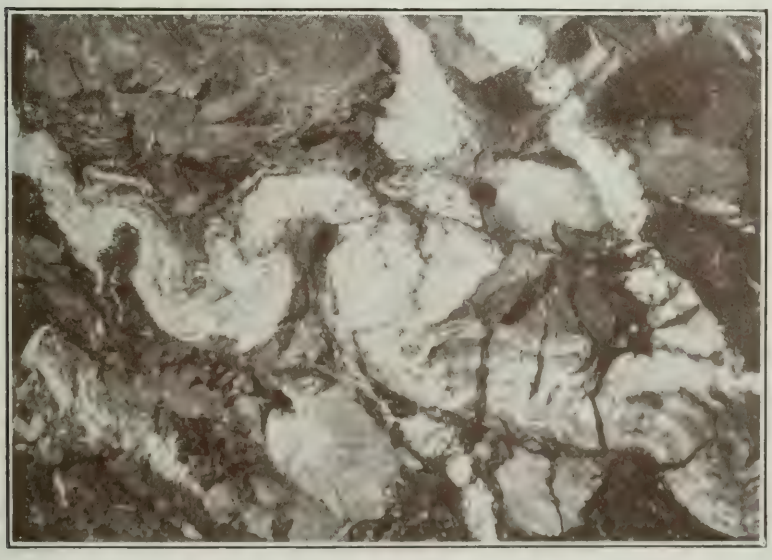
No. 20A.—Montreal Co.'s quarry at Moose River.



No. 19.—Old workings on the Taylor vein at Moose River.

No. 21.—Cleavage above the Cameron vein at Ecum Secum.

No. 8.—Synclinal portion of the Borden vein at Mount Uniacke.



No. 22.—The Richardson vein, with cross stringers.

No. 23.—The Donkin lode in the Beaver Hat mine, at Isaac's Harbour.

Waverley.

Isaac's Harbour.

A series of small mines at Montague.

Old workings at South Uniacke.

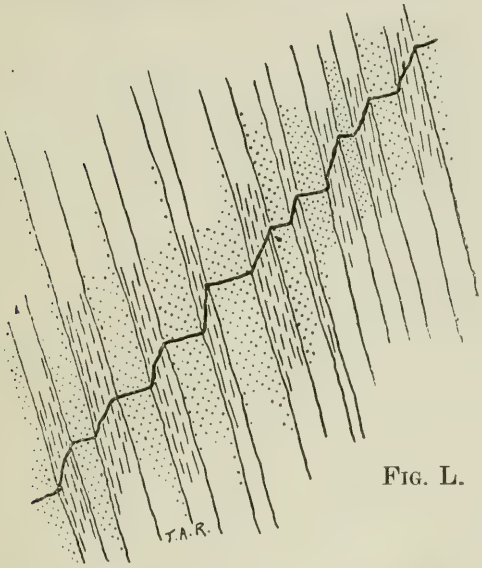


FIG. L.

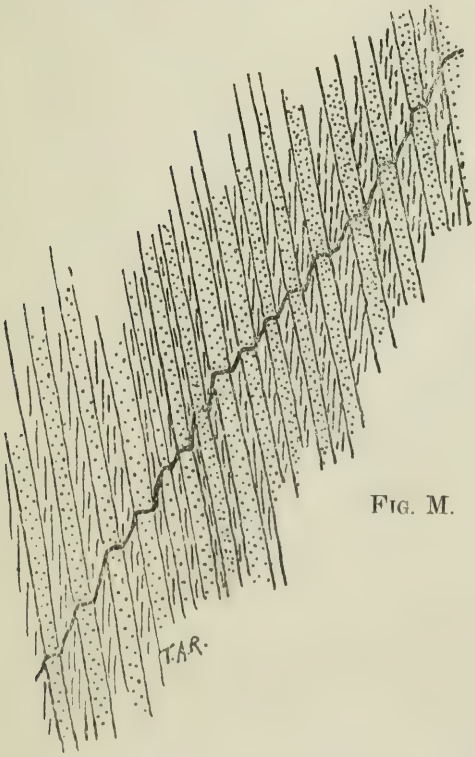


FIG. M.

it confines its divagation to one soft bed—of slate; in part it responds to the invitation of the cleavage-lines; in default of such assistance it traverses both bedding and cleavage, but not for long. A vein-fracture in one mine plays many parts. That was the lesson at Bendigo; that is the teaching of Nova Scotia.

When the solutions containing both quartz and gold began to course along the fractures thus prepared, they were deposited wherever conditions were favourable, and after deposition they tended to reproduce the character of their abiding place. Thus I argue that they were precipitated along the bedding-planes, to form the simply tabular deposits that delight the writers of text-books; they likewise were laid down along the arches that gave us the symmetrical saddle-lode; they rested in cross-fractures that became the 'spurs' of Bendigo and the 'angulars' of Nova Scotia; and, finally, they found a way into the intricate and rhythmically-crinkled passages prepared for them, where cleavage and bedding disputed for structural mastery.

As far as I know, only one writer has made a detailed study of the crenulation. I refer to Mr. J. Edmund Woodman, formerly Professor of Geology in Dalhousie University, at Halifax. His paper on the Moose River district, to which reference has previously been made, is a good example of careful investigation. The accompanying drawings are excellent. They afford evidence that the crenulation is usually confined to one side of a fold, that it is found on cross-veins as well as on the stratified veins, that the laminæ of the enclosing slate tend to curve with the quartz, that the crenulation is most common in slate beds bounded on both sides by quartzite, that the sympathetic curves in the rock rarely reach more than 2 ft. from the crenulated vein, and that the furrows are larger where not parallel to the bedding. He recognizes strain-slip cleavage, and says that "if it caused the corrugations, we should find some sign of it also in the sediments, either cleavage or acute small-scale folding; but do not." He adds that "there is not the slightest deviation in the dip of the laminæ in proximity to the veins," but I cannot reconcile this with the statement that "the lamination of the slates follows the crenulations of the lead, exactly when near it, less faithfully when farther away." If the "devia-

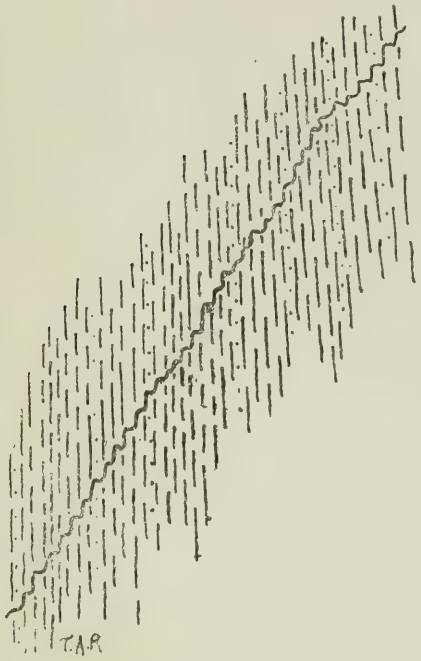


FIG. N

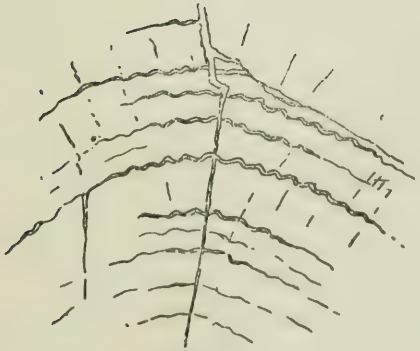


FIG. O

tion'' of the laminæ is not from the normal dip, from what line is the deviation? Dismissing strain-slip cleavage, Mr. Woodman says: ''The only explanation remaining, therefore, is that the cross-veins lie in fissures which had their present sinuous course at the beginning of occupancy by the vein material. It is noticeable that this crenulation is not found in quartzite unmixed with slate; but is confined to slate and alternations of the two. It is best developed where no quartzite is present. It appears, then, that in the thinly laminated pelites,* at the time of instrusion of the cross-veins, the rock broke under the strain most easily across the strata squarely or diagonally in places, with the bedding in others, and in some backward or downward rather than upward.'' Thus I infer that Mr. Woodman and I reach the same conclusion by diverse ways. I had not read the foregoing paragraph until after arriving at my own conclusion. And I reached it by two suggestions: first, the coincidence between the pitch of the crenulation and the line of intersection between the planes of cleavage and bedding, as noted by me in 1905, and, secondly, the analogy of the cross-veins as sketched by me at Bendigo in 1890, showing the zigzag structure when the quartz-filled fracture crosses alternate beds of slate and sandstone. Then came the evidence of such photographs as Nos. 19 and 20, where radial cleavage is seen to be traversed by veins of crenulated quartz. On turning to Mr. Woodman's paper I noted his sketches of cross-veins accompanied by crenulation, but it was not until writing the foregoing paragraphs that I ascertained how closely his conclusion tallied with my own. We express it differently, but the fundamental idea is nearly identical. He wrote in 1903.

Thus the crenulation may finally be regarded as the beautiful product of complex fracture due to cross-folds in rocks of uneven texture. The fissility induced by extreme plication has afforded a sinuous line of passage to rupture and to the quartz that subsequently healed the rupture. As originally formed the veins were crooked, that is, they zigzagged in a sharply angular line. In the course of mineral impregnation they became

*A pelite is a rock composed of fine mud.

rounded. Nature hates an angle as she abhors a vacuum. Time softens hard lines is a poetic way of saying that chemical corrosion is most rapid where the largest surface is exposed to solvent action. The angles of the zigzag vein-fracture were filled with quartz, which, in the course of accretion from further passing solutions, replaced the crushed slate adjacent to it and slowly gained a rounded outline. On the 700-ft. level in the Gagnon mine, at Butte, I have seen boulders 5 or 6 feet in diameter, formed by the solvent action of water that had seeped along joint-planes in the granite. These were similar in origin to the boulders formed by erosion at surface, and were due to the sculpturing hand of chemical waters. Once rounded, the hard quartz bent the neighbouring soft slate to its unyielding shape. Neither movement nor solution cease underground at a given moment. Since the veins were formed, the continual shifting of loads of sediment, by transfer from mountain to river, from land to sea, has caused that disturbance of equilibrium which incites geologic unrest. This has been the cause of new fractures along which later solutions have found a patient way. Photograph No. 22 shows clearly the occurrence of quartz veins differing in character and origin. We who see a vein in a mine to-day are apt to regard it as a finished product, brought to our attention at the close of a completed cycle of chemical and physical operations. We regard ourselves as full-stops in time. On the contrary, the whole of the period during which man has tenanted the earth barely punctuates the geologic record; ours is a brief phase synchronizing with a minute portion of the vast stretch of time during which the vein of ore has undergone successive change. Had we left it in the ground it would have undergone, in later eons, a further alteration. When we remove it with the pick and hammer we break the normal sequence of its development; we are for a brief moment the masters of forces that have operated since the dawn of creation.

PART II.

INTRODUCTION.

In 1905 I was engaged by the Government of Nova Scotia to examine and report upon the goldfields of that Province with a view to giving advice concerning the best method of stimulating a declining industry. After I had completed my investigation of the gold-bearing lodes of the country I turned, as was proper, to the descriptions and explanations published by earlier investigators, and in ransacking the literature of the subject* I found delightful evidence of the growth of geological thought from 1860 to the present day. This evidence can be summarized in the form of a series of quotations, accompanied by my own comment, and it is here proffered as a contribution to the study of economic geology.

Before citing a succession of observers, I shall ask you to remember that the longer axes of the saddles and domes, on which the ore is found, have a strike from east to west, that is, parallel to the backbone of the peninsula of Nova Scotia, with cross-folds extending roughly from north to south. Next it is necessary to explain some of the terms used by earlier writers and sanctioned by local usage: 'Lead' is used as a synonym for 'lode.' The slate is variously called 'shale,' 'clay slate,' 'argillite,' and 'belt.' The last of these is also a synonym for 'bed.' The quartz is said to lie in the 'belts' of slate. The quartzite is called 'sandstone,' which is not far wrong, although the rock in question is undoubtedly crystallized by metamorphism. Another local synonym for quartzite is 'whin.' This, of course, is an old British term applied to the trap-rock forming the base of that horizon in the Carboniferous in which are found the lead deposits of the north of England, notably at Alston Moor. Used thus it is the equivalent of the Cornish 'elvan.' As applied to the Nova Scotian quartzite it is entirely wrong, and serves merely to perpetuate an early error. Both 'belt' and 'whin'

*In which I was greatly aided by a bibliography placed at my service by Mr. J. Edmund Woodman, then professor of geology in Dalhousie University.

are localisms of a pernicious character, because any special significance that they may possess is misleading.

Gold was discovered at Waverley* in August, 1861. Earlier discoveries had been made at Tangier, in 1860, but they proved unimportant.

JOHN CAMPBELL.

In 1863 John Campbell made a report to the Provincial legislature. He spoke of the 'whin' as the fundamental or basement rock of the region and drew a section showing that "it comes to the surface six times between the Atlantic coast and the northern boundary of the gold district, say 30 or 40 miles. As in each case the associated rocks accompany it, and with them the auriferous quartz, it is plain that this structure is clearly established, and there must be not less than twelve parallel zones at an average distance of not more than three miles from each other, in which the explorer may reasonably look for the occurrences of gold-bearing quartz."

Evidently he looked for the gold on the sides of the fold, not along the apex. He also assumed that the stratified rocks were continuous sheets, not flat discs. As the quartz also is supposed to be inter-blanketed without a break, we may infer that he imputed the absence of it along the anticlinal crest to the effects of erosion.

JOHN ARTHUR PHILLIPS.

Campbell quotes John Arthur Phillips, who apparently visited the Waverley district at this time (1862-'63). Phillips says: "The principal workings are here situated near the summit of a hill composed of hard metamorphic shales, where openings have been made to the depth of 4 or 5 feet, upon a nearly horizontal bed of corrugated quartz of from 8 to 10 inches in thickness."

He does not appreciate the anticlinal structure, and this failure to notice a dominant feature may have been due to the small extent of lode then exposed. Apparently the ore had only just been uncovered on the crest of a flat dome, so that it looked like a horizontal layer. Proceeding, he says:

*Originally it was Waverly; probably from an error in spelling.

"This auriferous deposit is entirely different from anything I had seen before, and when laid open presents the appearance of trees or logs of wood laid together side by side, after the manner of an American corduroy road. From this circumstance the miners have applied the name of 'barrel quartz' to the formation, which, in many cases, presents an appearance not unlike a series of casks laid togather side by side and end to end. The rock covering this remarkable horizontal vein is exceedingly hard, but beneath it, for some distance, it is softer and more fissile. The quartz is itself foliated parallel to the lines of curvature, and exhibits a tendency to break in accordance with these striæ."

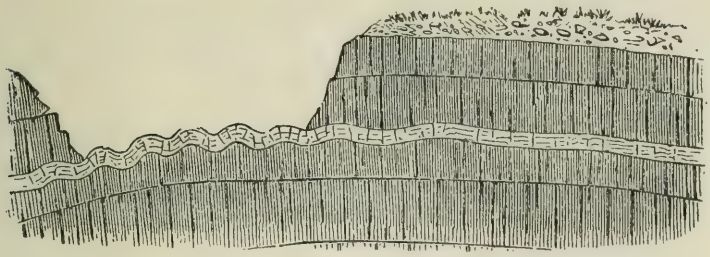
BENJAMIN SILLMAN, JR.

In the following year a famous American geologist, Benjamin Silliman, Jr., offered a description of the Nova Scotian goldfield in a paper published at New Haven, in February, 1864. He made reference to the strong marks of glaciation and the proofs of extreme denudation. Mention is made of "the universal evidence of a high degree of glacial action, which has so worn down and polished the rocks that their edges everywhere resemble the leaves of a book which has been cut with a dull knife in the binder's press; in a direction at right angles to that of the leaves."

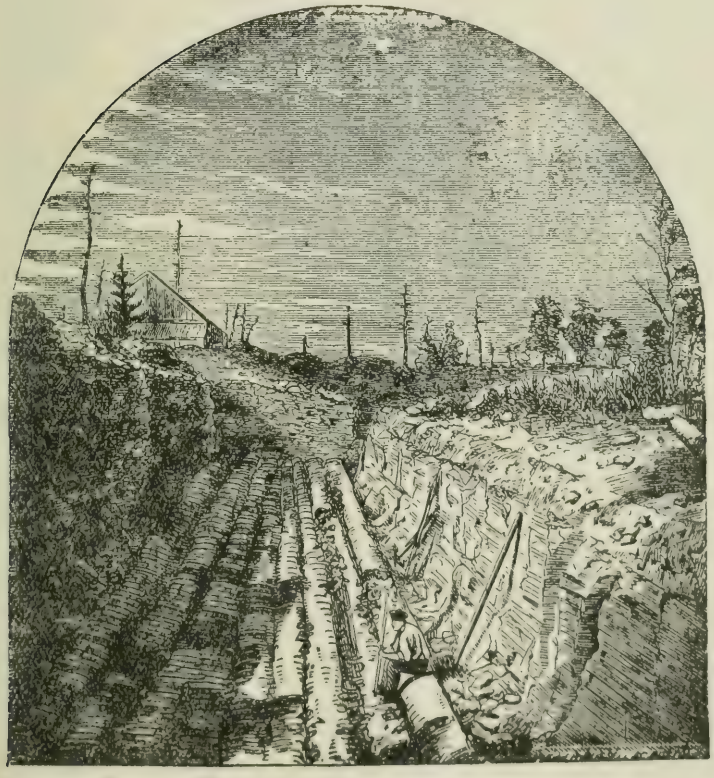
Early observers, seeing a few patches of glacial drift, had imagined the existence of large gold-bearing alluvial deposits, hidden in lakes and marshes. Silliman however, pointed to the marks of denudation and stated that "they account, in fact, for the general absence of alluvial gold." "The great mass of loose materials which come from the scouring of the country by glacial action has gone into the Atlantic ocean, where the gold is safely deposited."

He gives a section and a perspective view of the Waverley deposit (see opposite page), and says:

"Only the corrugations in the open part of the cut are visible; the extension of the vein to the right and left is ideal, the superincumbent mass covering it. I measured, however, the quartzite above, dipping to the right and left at a small angle, and I think no geologist would doubt that the crest of an anticlinal axis here comes to the surface and has escaped the denudation which has removed the top of the crest in most places. The corrugations, or folds, appear to be accounted for on the supposition of a lateral thrust producing the undulations. The annexed perspective view of this interesting locality is taken from a stereoscopic photograph, showing the appearance of the barrel quartz after the surface rock (quartzite) has been removed, and before the miners have broken up the quartz layer for removal."



Cross-section of the Waverley deposit according to Benjamin Silliman, jr



General view of the Waverley deposit as sketched by Benjamin Silliman, Jr.

It is obvious that Silliman made an acute diagnosis of the structure and we shall see that many years passed before any later scientist was able to throw fresh light on the subject.

T. STERRY HUNT.

Four years later, in 1868, a celebrated chemist and geologist, T. Sterry Hunt, made a report for the Geological Survey of Canada. He quotes Campbell as having drawn attention to "the grain or reed-like marking often impressed on the surface of the beds in a direction parallel to the east and west axes of folding, and he points out that the angle of dip, eastward or westward, of these markings on the crown of the great anticlinals enables us to detect the transverse, or north and south, lines of undulation, which have at a subsequent period disturbed the horizontality of the east and west anticlinal folds." It is obvious that for the "angle of dip" we should read 'pitch.'

Hunt himself proceeds to say:

"The markings in question often appear as rib-like ridges or flutings, which are most conspicuous on the surface of the auriferous quartz layers and the enclosing beds. On the summits of the anticlinal folds they are sometimes so large and so well defined as to give the layers a wrinkled or corrugated form, producing what is designated in the region as 'barrel' quartz, and has by some observers been compared to the ripples on water, and by others, to that parallel arrangement of logs which is seen on what is called a corduroy road."

In explaining the origin of the deposits of gold-bearing quartz, T. Sterry Hunt says:

"So far as my present observation goes, I think that to describe them otherwise than as interstratified beds would be to give a false notion of their geognostic relations. The laminated structure of many of the lodes, and the intercalation between their layers of thin continuous films or layers of argillite, can hardly be explained in any other way than by supposing these lodes to have been formed by successive deposition at what was at the time, the surface of the earth. There is, moreover, evidence that these laminæ were formed before the lodes were folded and contorted; this is furnished by some remarkable specimens of the so-called barrel quartz which I took from a lode at Upper Stewiacke. . . . It seems not improbable that the corrugated structure of the lodes, which gives rise to the barrel quartz, is due to the difference in texture, and to the greater resistance to lateral pressure offered by the quartz layers than by the enclosing beds of clay and sandstone, which by their consolidation have given rise to the argillites and quartzites."

Thus he supposes the quartz to be an original member of the sedimentary deposit in which it now lies embedded and he imputes the crenulation to subsequent folding. The corrugation

of quartz and the corresponding fluting of the rock encasing them are essentially different from ripple-marks, such as, for example, I saw on the foot-wall of the Johnson's Reef mine at Bendigo.* The efficacy of lateral pressure alone is negatived by the fact that the 'barreling' or crenulation is exhibited by veins that cross the stratification.

HENRY Y. HIND.

The next observer to write on the subject was Henry Youle Hind, who published a report in 1869. He had an active imagination, for he says: "A very feeble conception can now be formed by superficial observation of the original enormous magnitude of these huge waves of rock which ridged the surface of the Province. Whether denudation took place as fast as the uplift, or whether the undulations attained their maximum altitude, partially or wholly undenuded, it is certain that not less than 9,000 ft., in vertical thickness, belonging to one rock series, have been removed from the present surface of the Waverley gold district."

He speaks of 'whin, quartzite, and slate,' and assumes the 'whin' to be of igneous origin. Having imputed a volcanic character to a sedimentary rock, he next credits the quartz lodes with a sedimentary derivation. He says: "The so-called veins, leads, or lodes in which the gold is chiefly found, are true beds of aqueous origin, and formed by deposition in the same manner as the associated quartzites and slates with which they are interstratified, and indefinitely prolonged in all directions."

In order that we may not be mistaken as to his idea of the true character of the 'whin,' he explains that "under the general name 'whin' are included a variety of rocks which are correctly known as diorite, diabase, dolerite, etc.: but for the sake of simplicity these will all be comprehended in the general description under the term 'whin.'"

Hind's idea of simplicity is to ignore facts. However, in his description of the details of lode-structure he exhibits powers of observation better disciplined. He says:

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*Trans. A.I.M.E., Vol. xx, p. 519.

"At Waverley, movement has occurred between the quartz and the whin, or between the quartz and hard slate, or in the bands of slate, and in all cases slickensides, reed-like markings, ripples, and small undulations have been produced. In the barrel quartz no sliding motion is distinguishable, for the corrugations extend far into the overlying whin rock until they assume the form of a series of connected arches 5, 6, and even 7 ft. in width. The corrugations are by no means confined to the quartz lead, but spread out, fan-like, into the overlying rock."

He distinguishes between "true" veins, namely, the feeders that cross the stratification, and the "bedded" veins of the domes, thus: "While the gold which the bedded leads contain, in common with other metals, was most probably derived from the oceanic waters from which the quartz was deposited, the gold in the short segregated veins of subsequent origin was transferred from the bedded leads or auriferous interstratified slates." He makes note of the fact that at Montague, Sherbrooke, and Lawrencetown, the rich quartz or 'gold streak' dips (he means 'pitches') at the same angle as the corrugations. He attributes the occurrence of these richer portions to precipitation by organic matter, saying: "It would be a simple matter to explain the structure of the gold streak on the supposition that organic matter determined the deposition of the metal in belts or zones, for it is easy to conceive accumulations of stranded organisms on subaqueous beaches in a shallow sea in the form of long bands."

This coincidence between the pitch of the rich ore and a large corrugation or 'roll' is an important fact, as has been proved by many small but successful mining operations in Nova Scotia. The "stranded organisms" are not confirmed by the evidence of vegetal remains, but it is true that slate is more plentiful at the anticlinal crests.

In a later essay, read before the Geological Society of London, in April, 1870, he discusses the 'gneisses' of Nova Scotia. These he supposed to overlie the granite, for he says: "The granite is a sedimentary deposit, and consists of two deposits resting unconformably upon one another." He mistook the effects of contact metamorphism and the schistose character given in places to the quartzite-slate series. As apophyses (dikes or tongues) of granite penetrate the overlying altered sedimentary rocks, he allows that "the granite, or rather gneisses, break

through the gold-bearing series in many places, but they are brought up by faults. In other places the gneisses appear to have been in a plastic state when the uplift took place,* for veins are found squeezed into the cracks and interstices of the thin bedded gold-bearing rocks, and it is this aspect which leads at the first blush to the impression that the granite is an intrusive rock, and not a lower series brought up by a fault." This explanation is itself not wholly unreasonable, but it is negatived by abundant facts, ascertained since Hind wrote.

In describing the mines at Sherbrooke he distinguishes between lodes that are "intercalated, and consequently of later age than the contemporaneous beds." The last two words refer to the interbedded seams of quartz, which he thus distinguishes from the quartz that appeared to him to be unstratified. He goes on to say:

"In broad bands of slate, lodes thicken to the breadth of 10 to 12 inches and thin out to a film of quartz or disappear altogether in the space of a few hundred feet. But before they thin out altogether, another lode begins to appear, separated from the first by a few inches, more or less, of slate and quartzite. This cannot be strictly regarded as a continuation of the lode which has thinned out—although it may thin out and be in part overlapped by another lode in the strike of the first one which has disappeared. Some lodes of this description appear to belong to the class of intercalated lodes, that is, they are sheets of quartz that have been formed at a later date than the enclosing rock, and were produced by the replacement, particle by particle, of pre-existing beds of some other soluble material. In lodes of this class, which generally occur in slate, the slate itself is found to be auriferous, and the whole mass is frequently worth crushing. The strong persistent lodes generally occur in quartzites, or with quartzites on one side and slate on the other. The intercalated lodes occur in slate, with sometimes thin beds of quartzite, which are also intermittent, that is, 'thin out' and 'take up' again."

Here he recognizes that the quartz assumes the shape of flat discs or lenses, following each other *en echelon*, and he is on the track of the truth in imputing their form to the replacement of soluble sedimentary material. It is strange that he did not take the next mental step, and inquire whether the regular layer-like forms of quartz were not also a replica—in part at least—of rock replaced by silica.

The recognition of quartz in fissures crossing the stratification, and therefore later than the enclosing rock, is shown in

*The text says: "In a plastic *slate where* the uplift took place." Obviously typographical errors.

another paper read before the Society of Arts, in May, 1870. On that occasion he said: "I consider that all the evidence hitherto accumulated in Nova Scotia tends to show that the gold was originally deposited from oceanic waters, and diffused throughout their sediments, especially in beds of quartz. Much of it was no doubt subsequently concentrated in intercalated beds of quartz, and in some instances in fissure veins." Thus he falls back on Werner's theory of the precipitation of the metals from oceanic waters, and he assumes that the quartz is of sedimentary origin also. If the gold and the quartz were both of sedimentary origin, we should find the gold, by reason of its gravity, concentrated at the bottom of the quartz sediment, that is, on the foot-wall. Hind discards the idea of thermal action due to igneous irruption; he wrote long before hydrothermal activity in forming metallic ores was a recognized theory and at a time when plutonic action was only vaguely surmised. Even this agency he rejects, for he says: "There is no evidence to show that intrusive rocks, or veins, or dikes had any share in the introduction of the gold; indeed, I have not yet seen any rocks in Nova Scotia near the gold districts, which, upon close examination and study, can be regarded as intrusive rocks. Gold is found and worked in beds of quartz of contemporaneous age with the interstratified slates and quartzites, throughout a vertical thickness of 6,000 ft. These beds are worked in one district or another throughout that thickness of strata, on anticlinal or synclinal folds." He is not aware of the diorite at Tangier, and he has failed to note that the granite exhibits its intrusive character in many localities.

In his description of Waverley, he is off the dangerous domain of theory, and does himself more credit. He says: "The so-called barrel quartz at Waverley is a fair representation of a corrugated lode, occurring on the crown of an anticline. In nearly all the gold districts the same form of quartz beds may be seen, and in similar relative positions. The corrugated structure is not confined to the quartz, but spreads fan-like into the overlying rocks, and appears to be, in part, the result of unequal pressure during the folding of the strata."

WARINGTON W. SMYTH.

At the meeting of the Society of Arts, in London, before which this paper was read, the chairman was Sir Warington W. Smyth. He was the only person present who cared to criticize Hind's theory, and he did it, as we should expect, in an effective manner. Smyth asked:

> "If the gold has been deposited contemporaneously with the quartz by the sea-water, why was not all the gold deposited at the bottom of the sediment, by reason of its greater specific gravity? But by another part of the paper it appeared that the gold ran only in streaks, and that it seemed to be accumulated near certain crossings of these beds by other lines of quartz, which looked more like true veins. At present, therefore, he could not help saying he thought there was a good deal more to be made out. He had on former occasions visited certain localities, though not in Nova Scotia, where it was said that minerals occurred throughout a stratified mass, but he had usually found such a statement to be the result of a deficient observation. In a certain part of the stratified-looking mass there had been a dissemination of mineral matter, but very frequently this apparently stratified mass was nothing else but a mass of stratified material, ground and rubbed together, and existing between two walls resembling those of a regular vein; or, again, the mineral matter had been most decidedly intercalated at a period long subsequent to the original formation of the beds. He could not help thinking that this would prove to be the real explanation of the occurrence of the gold in a great part of these Nova Scotia deposits."

Thus Smyth placed his wide general experience against Hind's local knowledge. The reference to 'streaks' requires explanation, that being the word used in Nova Scotia for the richer portions of the quartz, that is, ore-shoots. It is a misleading term, for the 'streak' is not a line or thread of rich ore, but a band that may be many feet wide, pitching at a strong angle, as determined by the 'rolls,' to which reference has been made, and by feeders or cross-veins that do not conform to the bedding of the country-rock and therefore penetrate the walls of the normal anticlinal sheets of quartz. Undoubtedly Smyth was right in placing his finger on this significant fact, a fact that suggested so obviously that the deposition of the gold could not be due to sedimentation.

ALFRED R. C. SELWYN.

In the folowing year, 1871, Alfred R. C. Selwyn, famous as an Australian geologist, published his "Notes and Observations on the Gold Fields of Quebec and Nova Scotia." He expressed disagreement with Hunt and Hind, and quoted with approval

the generalizations of Lieber (Geological Survey of South Carolina, 1856). Selwyn repudiates the idea of contemporaneity as between the quartz and the sedimentary rocks. He says:

"All veins are younger than the country; and hence it is without any reason that many writers regard those only as veins which dip or strike unconformably with the country-rocks, for it is evidently quite immaterial what peculiar relative position is occupied by the two as concerns the origin or the general characters of the veins. Crevices may be formed in any direction, and it is but reasonable to suppose that the planes of stratification, being possessed of less cohesion, will at least as readily present themselves for the formation of cracks or fractures as those planes which traverse the more compact and less fragile portions of the rock."

In other words, the origin of an ore deposit cannot be inferred from its shape, because the shape is dependent upon structural conditions in the country-rock. The ore in veins occupies fractures that follow lines of least resistance, and those lines may be identical with the stratification. Selwyn continues: "In order to substantiate their origin by contemporaneous deposition at the surface, it would likewise require to be explained in a more satisfactory manner than has yet been done, why they are always found in close connection with anticlinal axes, and never at the outcrops of the main synclinal folds, or associated with strata which have not been subjected either to metamorphic agencies, or to folding or faulting." To which I may add that if the quartz had been deposited in a sheet-like layer, sandwiched between silt and sand, at the bottom of the ocean, or even in the flat discs characteristic of sedimentation, it would now be found wherever the quartzite and slate outcrop. Nor would we expect to find it particularly at the crest of the folds, for the pressure incidental to folding would have bent the beds in places where the least quartz offered the least opposition to plication, and not the places where the hard layer of quartz was thickest. But you would rather hear what else Selwyn has to say; he continues thus:

"The vein-like character of the quartz, the comparatively limited distances through which the layers have been traced, their more or less lenticular form, the evidences of motion in the enclosing rocks, the constant connection with anticlinal axes, and the absence of corresponding quartz layers through great thicknesses of strata which do not present evidences of such disturbance and corrugation, are circumstances, all of which are strongly opposed to the theory of contemporaneous deposits and as strongly in favour of the opposite conclusion."

As regards the granite of the Nova Scotian gold-mining region, Selwyn observes:

"It is strictly of an indigenous character, and neither an old granitoid gneissic series of Laurentian age, nor an intrusive mass. Dr. Dawson has shown ('Acadian Geology,' 1868) that in different parts of its course it comes successively into contact with Lower Silurian, Upper Silurian, and Devonian rocks, and the manner in which these sedimentary strata are affected at the lines of contact scarcely leaves room to doubt the posterior origin of the granite. . . . The relations of the granite and gneissic rocks in Nova Scotia to the surrounding auriferous strata, are perfectly analogous to what is observed in this respect in the Australian gold districts, most of which are in close proximity to similar granitic centres. In one instance an auriferous quartz vein, which had been worked close up to the boundary of a large granitic area, was found to pass gradually, by the addition of feldspar and mica, into granite, losing its auriferous character and becoming a vein of ordinary grey granite exactly resembling the rock of the neighbouring granite mass, into which it eventually merged. It will be interesting to trace out the manner in which the quartz beds in Nova Scotia terminate in their strike toward the granite masses."

The comparison with Bendigo and Ballarat is just, as I can testify. The argument can be made stronger by reasoning that the branch or apophysis of granite that penetrated the quartzite and slate lost its mica and felspar, gaining in quartz, until it became like an ordinary quartz vein, acquiring an "auriferous character," and becoming a vein of quartz "exactly resembling" the neighbouring anticlinal formations "into which it eventually merged." The differentiation from a dike of granite containing quartz, mica, and felspar to a simple quartz vein, recalls the modern theory advanced by J. E. Spurr that some veins of silica or 'alaskite' represent the last phase of magmatic segregation. Selwyn's question as regards the behaviour of the quartz veins when reaching the granite in their strike has been answered by mining operations that have followed such veins from the slate and quartzite into the granite. The quartz penetrates the granite and has been found gold-bearing, although not rich. The veins maintain their identity, but not for long, after entering the granite; and there is evidence to suggest that the quartz is an extreme phase of the silicification to which, in places, the granite itself has been subject.

Coming to the barrel structure, Selwyn says:

"The facts which I have observed lead to the conclusion that the corrugation of the quartz is intimately connected with, and dependent on, the operations of the forces which have produced the slaty cleavage; the same forces have likewise, in all probability, caused the opening between the beds in which the quartz has been deposited; and also the great parallel east and west synclinal and anticlinal foldings of the strata. In every corrugated vein which I have examined, the axes of the corrugations or barrels always coincide with the strike of the cleavage. If the walls are

of sandstone (whin), they are rarely corrugated, and seldom show any cleavage planes; though their surfaces, especially if in immediate contact with the quartz, frequently show ridges or parallel undulations, which strike with the cleavage and seem to have impressed corresponding swells or undulations on the quartz. Where cleavage and bedding coincide in strike and dip, no corrugations occur, nor are they observed in layers which are enclosed between walls of hard whin. All those veins, which are sharply corrugated and contorted, lie within the limits of beds of highly cleaved soft slates of from three to five feet wide, between beds either of whin and a hard compact slaty rock, which constitute the walls of the veins, but in no instance exhibit corrugations corresponding with those of the vein, and are commonly perfectly smooth and even throughout.''

Here Selwyn is on the edge of a discovery that would have gone far to explain the origin of the 'barrel' structure, Whether he expressed himself badly or whether he really appreciated that the 'corrugations' follow the line of *intersection* between the planes of cleavage and the planes of the vein-walls is not clear. He certainly afforded a hint to succeeding observers, but no sign is given that they appreciated it.

HENRY S. POOLE.

In 1878, H. S. Poole reported that:

''The distinctive features of the gold leads of Nova Scotia are their general conformability with the slate and quartizite beds and their regularity suggesting that they are beds rather than veins. But there are characters that point to their being true veins in spite of these features, and they are the following: the roughness of the planes of contact between quartz, slate and quartzite; the irregularity of their mineral contents; the termination of the leads; the effects of contemporary dislocations; and the influence of stringers and off-shoots on the richness of the leads, characters that simply or collectively it would be difficult to account for, associated with a stratified deposit.''

Mr. Poole is, I believe, still happily living. I hope he may long be spared, for he injected a notable amount of good sense and keen observation into his writings on the subject. Obviously his distinction between 'beds' and 'veins' is well put and conclusive.

In the following year (on March 12, 1879), the same observer read a paper before the Geological Society of London, and again combated the old ideas of Hunt and Hind; for he said: ''The theory that the 'leads,' as the lodes are locally called, are contemporary beds with the slates and quartzites has not since been generally accepted; nor has it gained ground with the further knowledge derived from working, nor been adopted by any of the miners, among whom are men experienced in other

gold-producing countries.'' The only persons contributing to the discussion on this occasion were J. Arthur Phillips, who ''confirmed the views of the author as to the leads of Nova Scotia being true mineral veins,'' and Warington W. Smyth, who stated that ''he thought the author of the paper had rendered a most useful service to geology in completely upsetting the theory (based on imperfect observation) of the bedded origin of the leads.'' Thus a fallacious idea was given its quietus; in later descriptions and discussions the notion that the lodes were interstratified sedimentary deposits is conspicuous by its absence.

In referring to the Waverley deposit, Poole says:

> ''In the overlying stratum the position of the plication in the quartz is marked merely by a moderate undulation. The quartz having yielded in the greatest degree to the lateral pressure would indicate that, at the time of the upheaval, it was then in a more plastic condition than the containing rocks, and the more when it is observed that the rolls contain angular fragments of slate, and send off shoots and tongues of quartz up into the superjacent stratum.''

The notion that the extraordinary serpentine folds characterizing the 'barrel' structure must have been rendered possible by a plastic condition, assumed by the quartz by reason of excessive pressure, is not undeserving of respect; it affords one of the explanations most favoured by other geologists who came to Nova Scotia long after Poole; but it is rendered untenable by the evidence submitted by me in the first half of this paper. The ''offshoots and tongues of quartz'' penetrating ''the superjacent stratum'' require us to suppose that the quartz was not only sufficiently plastic to permit deformation without crushing, but also to imagine that the silica was in a molten or fluid state. If that condition had been attained owing to excessive pressure and temperature then the slate and quartzite also, both of which are more susceptible to the same physical change, would show it. They would not have remained so hard as to be traversed by cracks into which the liquefied or viscous silica could be injected.

Edwin Gilpin.

After Poole came Edwin Gilpin, the Provincial Inspector of Mines, who contributed a paper on ''The Gold Fields of Nova Scotia,'' to the North of England Institute of Mining and Mechanical Engineers in 1881. He drew attention to the comparative

smallness of the lodes. "The worked veins vary in thickness from ½ in. to 6 ft. The usual width being from 4 to 8 in., and a 20-in. vein is considered a large one." He spoke of "beautiful specimens of gold" to be "secured by treating nodules of pyrites with acid, which presents the metal in curiously interlaced plates and films, when by a previous examination no gold could be detected." Thus by strong acid is obtained swiftly a reaction such as ensues in nature slowly when the oxidation of pyrites yields a soluble sulphate, which is removed by weathering, leaving the gold in honeycombed pockets. Gilpin also gives a section across the Belt lode at Montague, illustrating how the 'pay streak' or enriched portion of the quartz lode is found at the intersection with a cross-vein.

JOHN WILLIAM DAWSON.

Next we come to an authority of the first rank, John William Dawson, the Principal of McGill University. As early as 1878 he stated that "the gold deposits seem richer in the vicinity of the granite," and at the same time he re-affirmed his view that "the granite intrusions and gold veins are roughly contemporaneous." In 1891, by which time he had been knighted, and was known as Sir William Dawson, he published "The Geology of Nova Scotia, New Brunswick, and Prince Edward Island." In that book he refers to the deposit of gold-bearing conglomerate at Gay's river, an occurrence important as affording evidence concerning the age of the gold deposits. He says:

"It was described in *The Canadian Naturalist* for 1864, by Mr. C. F. Hart, and Dr. Honeyman has favoured me with manuscript notes of a visit to the place in 1866. From these sources I extract the following information: The locality is at the junction of the Lower Carboniferous conglomerate with the slate and quartzite, forming the extremity of the ridge separating the valleys of the Stewiacke and Musquodoboit rivers. The slates belong to the Silurian gold-bearing formation, and contain small but rich auriferous quartz veins. The conglomerate is formed of the debris of these older rocks, and gold occurs in it exactly as in modern auriferous gravels, being found in the lower part of the conglomerate, and also in the hollows and crevices of the underlying slate. The fact is interesting, as showing that the gold veins existed in their present state at the beginning of the Carboniferous period, and that the causes which produced the modern gold alluvia were then in operation. By a later repetition of this process, the drift or boulder clay which overlies the conglomerate is at this place also slightly auriferous."

This is suggestive evidence. As Dawson says, a placer deposit was formed in the Carboniferous by the concentration of the

debris eroded from the gold veins formed in the Silurian period, and in a long subsequent era the Carboniferous gravel, hardened to conglomerate, became degraded and distributed in the drift of the Glacial period, and this in turn is washed into the river-beds of to-day. Dawson calls the prevailing formations 'Silurian.' A generation ago it was the fashion to impute Silurian age to gold-bearing slates of unknown geological antiquity; this tendency is to be debited to the example of Sir Roderick Murchison, who ventured the rash prophecy that gold was confined to rocks of Silurian age. We may also demur to Dawson's assumption that because gold derived from the quartz veins is found in a Carboniferous conglomerate, that therefore "the gold veins existed *in their present state* at the beginning of the Carboniferous period." This is an assumption echoed by later observers, but it may well be questioned. All that the facts prove is that the gold in the superficial parts of the veins was in a condition similar to that in which it is found to-day in the outcrops, but the outcrop of a geological to-day is not the outcrop of a geological yesterday; the processes of nature do not rest in idleness; solution and precipitation, re-solution and re-precipitation are continually at work. It is not safe to assume that because gold is found now at two or three hundred feet below the surface that it existed there in its present state before several thousand feet of overlying rock was removed by erosion and denudation. That false assumption vitiates many of the theories of a much later date.

Dawson quotes from notes made by him on a visit to Waverley in 1866. He says:

"The appearances showed that the barrel arrangement had constituted the crumpled crown of an anticlinal bend or arch—an explanation already given by Professor Silliman, and on one side the vein could be seen following the beds downward on the side of this arch. The arrangement indicates great lateral pressure; and, which is of more importance, proves conclusively that the quartz veins are contemporaneous with the folding of the rock, since they have perfectly followed its folds without fracture. That the auriferous quartz veins are not beds is evident from the manner in which they send off branches into the neighbouring rock, as well as from their own crystalline structure and the character of the imbedded minerals. They are undoubtedly true veins, but not veins formed by fracture of the containing rocks when in a hard and metamorphosed state. They have been formed and filled in the very act of the contortion and altering of the strata, and are thus of the nature of segregation veins,

gradually formed as the spaces containing beds were bent without fracture and with but litle crushing. The barrel quartz is most instructive as an illustration of this peculiar mode of formation, which must have occurred in the disturbance and metamorphism of sediments.''

Here we have another reasonable theory. A sedimentary origin for the quartz is not entertained, but the folding of the quartz must have been contemporaneous with the regional plication that made the saddles and domes. The addition of segregation as a factor in the formation of these curious lodes aids the theory undoubtedly, but it is not convincing in the light of later evidence. Dawson says that ''the quartz veins have perfectly followed the folds (in the rock) without fracture.'' This is not a fact. They do not follow the bedding-planes perfectly, but transgress those lines of structure most palpably. Returning to the question of origin, he adds:

''No geologist who examines these veins can, I think, doubt their aqueous origin; but different opinions may be entertained as to the precise mode of introduction of the metallic minerals. The facts already stated . . . appear to me to prove conclusively that the veins were formed at the time of the disturbance and alteration of the containing beds, and in consequence of the mechanical and chemical changes then in progress. In this case the gold and other metallic minerals were probably contained in a state of solution in alkaline sulphurets in the silica-bearing heated waters which penetrated the whole of the beds, and from which, as from a sponge, these and metallic matters have been pressed out in the folding and contortion of the beds.''

'Sulphurets' is used for sulphides. This old term still lingers in California. At one time it was employed to designate the sooty products of decomposition resulting in the early sulphatization of base-metal sulphides. However, that is by the way. The foregoing paragraph of Dawson is but supplementary to the one preceding, and elaborates the theory on which I have already animadverted.

W. R. THOMAS.

In 1893, W. R. Thomas, in ''Notes on Practical Mining,'' made some remarks in regard to the persistence of rich ore. He said:

''When one looks around at the many gold districts and sees a large number of mines that were once successful closed down, the first question that presents itself is: What is the reason why operations have been suspended? The usual local reply generally consisting of: Could not cope with the water; reckless management; had a barren streak for a few feet, and just before closing down, rich quartz was discovered right at the bottom of the deepest shaft; never should have stopped, etc. It is, in fact,

nearly impossible, according to local opinion, to find a mine that has been really closed down through barrenness. I have found, when making the inquiry, that the approximate depths of abandoned Nova Scotia mines is from 200 to 300 ft.''

This statement can be readily corroborated by mining engineers who have investigated abandoned mines in other regions besides Nova Scotia. In discussion, John E. Hardman stated that he had cut the top of the 'pay-streak' in the Standard Co.'s mine, at Oldham, at 520 ft. on the incline, or a vertical depth of 340 ft. The Wellington and Rose mines also are instanced as examples of profitable ore to a depth of 300 to 350 feet. This testimony only tends to confirm Thomas's generalization. The point is that the best ore did not reach far below the surface of to-day, although optimistic theorists would ask us to believe that the gold as now found existed in the same quantity and in the same ore at a time when the present surface rocks were covered by several thousand feet, since eroded, and they therefore expect us to infer that the rich ore may persist to an equal depth below the surface of to-day.

B. C. WILSON.

In 1894, B. C. Wilson read a paper before the Mining Society of Nova Scotia. He described the Waverley deposit as follows:

''In 1862, some drift quartz carrying gold was found on the top of the hill, and further search revealed the outcrop of a sheet of quartz lying nearly horizontal, covered with two to four feet of soil, and a corresponding amount of rock, and continued workings disclosed what might aptly be termed a blanket of quartz overlying the hill, and gradually dipping south, west, and north, but most decidedly to the west, or towards the lake at the foot of the hill, and several small owners soon made numerous openings on it, each apparently intent on forming open reservoirs for the local watershed, and, discounting the future for immediate results, soon got it in such a condition that no one could work it, notwithstanding the ore at one time was very remunerative.''

Eventually, in 1892, an adit 635 ft. long was driven from the lake and cut the lode on the crown of the anticline at a depth (on the pitch) of 200 to 250 feet below the old surface workings. Wilson proceeds to say:

''At the outcrop the lode was crimped or folded together upon itself and if smoothed out like a sheet of paper would have presented a vein not over 10 to 12 in. thick, but folded together it filled a space of 20 to 30 in., and with associated slate occupied a working belt of about 48 in. between the upper and lower enclosing walls of hard metamorphic rock, and when

denuded of the overlying rock presented the appearance of rows of barrels, and hence the name 'barrel lode' was applied."

The same observer makes an interesting reference to the effect of glaciation as evinced in Nova Scotia. He says:

"When, in the surface workings, the soil was removed from the rock overlying the quartz at or near the outcrop, the striæ or glacial footprints were such as to rejoice the heart of an enthusiastic geologist, and in fact many are yet visible on portions of the undisturbed rock. In one spot, where the auriferous vein protruded through its metamorphic covering, a strip of quartz probably 25 ft. long by 8 or 10 ft. wide had been exposed to glacial scouring, the inequalities worn down, and the quartz polished like a piece of ivory, and eroded creases, half-an-inch deep, cut into the retaining rock on either side, were continued straight on across this polished quartz, showing the continuous striæ or track of nature's great planing mill."

W. H. PREST.

In April, 1899, the prevailing idea of the persistence of gold in the lodes, independent of the surface of a recent geological period, and as being due to causes operating long before erosion had removed a great thickness of overlying rock, is voiced by W. H. Prest. He says:

"The original surface was many thousands of feet above our present shallow mines. But owing to the slow and ceaseless operation of denuding agencies, deep mining on a truly magnificent scale has been carried on. Stope after stope, and level after level were quarried by frosts and milled by icefields, but the gold and tailings were deposited in the broad Atlantic; 10,000 ft. was thus mined from the gold-bearing rocks before the present Caribou mines were exposed, and the present Moose River mines were not reached until 17,000 ft. more were removed in the same way. Although such an immense distance separates the respective geological horizons of these two mines, they are only five miles apart geographically. Now, are we to believe that any attempt, could it be made, to deepen the Caribou mines to the same geological level as the neighbouring mines of Moose River, will forever blot out the rich veins that have yielded so magnificently in the past? Are we to believe that the particular level reached by denudation in the present era of the earth's history limits the depth at which paying mines are to be found? And also that the veins and spots thus exposed by nature at such various depths, and almost where they begin, and that neither above nor below them has there ever been, or is there, any veins of value? This can only be maintained in connection with the theory that our present mines were originally but comparatively small spots in the centre of immense bodies of otherwise barren rocks and wholly unconnected with any source of hydrothermal action from below. To even the most superficial amateur in the study of practical geology this position will seem untenable."

This is a popular idea in Nova Scotia, and elsewhere. Unfortunately it is a fact that the orebodies bound by man do constitute "small spots in the centre of immense bodies of otherwise barren rocks"; it may be that if the exterior of the earth could be penetrated by the radio-active vision of a magician we should

see how few of these spots we had detected, but as to the relative smallness of them we should assuredly gain further proof. But those who recognize the sporadic distribution and the comparative insignificance of the miner's treasure-troves do *not* assume that they are "wholly unconnected with any source of hydrothermal action from below." The fallacy is to assume that because the action to which ore deposition is due is deep-seated therefore the ore must reach to a great depth. Because a river flows from a source 2,000 miles distant we do not assume that the pebble in the estuary has been carried 2,000 miles; it may have come from as far, but more probably it was torn from a bank less than 100 miles up-river. The language used by Mr. Prest is as expansive as his imagination; the mines to which he refers have not "yielded magnificently in the past." They were profitable little mines, but they did not uncover large orebodies; on the contrary, as compared to the masses of ore exploited in the Homestake, Alaska-Treadwell, Mount Morgan, and other famous mines, the gold-bearing quartz extracted in Nova Scotia represents little patches, mere fly-specks in the great thickness of pre-Cambrian rocks. If 10,000 and 17,000 ft. respectively have been eroded at Caribou and Moose River, and if the little quartz veins to be seen at the surface of the present geological period are the stumps of veins that once reached two and three miles, respectively, to the surface of a former period, then, of course, these same little veins may persist a few miles deeper and mining in Nova Scotia is in its infancy. But if we dig for a couple of hundred feet into the ground and find that most of these little veins die out or become barren, we shall have serious doubts about the advisability of sinking a shaft 5,000 ft. deep to exploit orebodies of imagined persistence. However, it is scarcely worth while to beat a dead dog; the subject will recur when further quotations have been presented.

E. R. FARIBAULT.

In March, 1899, a comprehensive paper on "The Gold Measures of Nova Scotia and Deep Mining" was read before the Mining Society of Nova Scotia by Mr. E. R. Faribault, an officer of the Canadian Geological Survey. This distinguished carto-

grapher said, in part: "The metamorphic rocks of the Atlantic coast form a continuous belt, from one end of the Province to the other, a distance of 260 miles, varying in width from 10 to 75 miles. . . . They cover about half the superficies of the Province, exclusive of Cape Breton island, and their extent may be roughly estimated at 8,500 square miles. Of this area, probably 3,500 square miles are occupied by granite masses, barren of gold, leaving an area of about 5,000 square miles of gold measures."

Incidentally, I demur to the term "gold measures," which suggests the continuity and uniformity of a coal seam, qualities by no means characteristic of the manner in which gold is found in nature.

From his own accurate and comprehensive surveys, Mr. Faribault has ascertained that in the eastern portion of the Province the thickness of the gold-bearing series of rocks is five miles, the upper slate group being two miles thick and the lower quartzite division three miles. He says that "some of the sharpest and highest folds have been truncated (by erosion) to a depth, as far as we know, of over eight miles, exposing at the surface a section of gold-measures of over five miles in thickness." The extrusion of the granite "occurred after the folding of the gold-measures and the deposition of the quartz veins; for the granite dikes and veins have been observed to always cut the interstratified quartz veins wherever they come in contact with them. The granite has thus no relation to the auriferous character of the veins and need not again be referred to."

This important point cannot be so summarily dismissed; apart from detailed evidence, which I shall be glad to proffer, it is not safe to conclude that the later age of the granite intrusion compels us to reject it as a factor in ore deposition. Quite the contrary. Ore deposits are not made at one fell swoop and then let carefully alone by all the geologic agencies that may in long succeeding periods come that way. If we allow that a gold-bearing quartz vein was formed at the time when the granite intruded we may infer that the igneous irruption was accompanied by structural changes and by the circulation of thermal waters, both of a kind likely to modify the character of the pre-

existing vein, especially as regards distribution of the gold. The ore found by man represents a long series of solutions and precipitations, diffusions and concentrations, brought about by chemical and physical conditions that varied frequently during that long time in which Nature has been at work. From the Devonian age of the granite to the human period so much time has passed as to stagger the imagination of a student with a test-tube in his hand. Nature is rarely content to let alone. Her processes are ever at work in a laboratory where the chemicals and apparatus have a potency that is rendered effective because the operator can draw a blank cheque on Time.

Mr. Faribault makes sundry comparisons between the lodes of Nova Scotia and those of Bendigo. Such comparisons are instructive, if made without prejudice; if distorted by misconception, they serve but to darken investigation. He says: "The Nova Scotia section of 35 miles gives 11 anticlinals, or an average distance of three miles between each anticline, and a maximum distance of nearly five miles; while in the Bendigo gold district it ranges from 300 to 1,300 feet. So that in Nova Scotia the amplitude of the folds is nearly 20 times greater than in Bendigo." This fact is mentioned as "a matter of great encouragement" to those mining in Nova Scotia, as if the amplitude of a fold were in direct ratio to its richnes in gold. By the same reasoning the huge fractures constituting regional faults would be more likely to contain valuable metallic ore than the small fissures in which the miner occasionally finds a reward for his persistent search. Mr. Faribault proceeds to say: "In Bendigo, where the folds are, on an average, twenty times smaller than in Nova Scotia, the legs of quartz are said to very seldom extend to greater depth than 100 ft. below the cap of the saddle-reef; which would correspond proportionately to 2,000 ft. in Nova Scotia." In the Shenandoah mine at Bendigo, it is true, an east leg was stoped continuously for a length of 550 ft. and to a depth of 180 ft., from above the 496-ft. level to the 665-ft. level. That is the maximum recorded. Mr. Faribault's figure is quoted correctly from my own description of Bendigo. Yet, even in theory, the height of a fold is not dependent on its amplitude, for steep folds are usually sharp. If the object of geological survey be

the discovery of ample folds and big anticlines, then it is worth while to institute such comparisons between Bendigo and Nova Scotia, but as the more immediate object is to facilitate the search for the precious metal, such discussions are as profitless as the ruminations of a scholiast. If an individual saddle-lode persists in depth to about 100 ft. at Bendigo, and proportionately, on the basis of a geological theory, the same kind of lode should persist to 2,000 ft. in Nova Scotia, we may ask: Where is the latter to be found? The object of mining is to exploit profitable ore and therefore to follow such ore as long as it persists. In Nova Scotia no mine has been operated profitably to 2,000 ft., or anything like that depth. It is futile to assert that the leg of a saddle should last to 2,000 ft. in Nova Scotia. It does *not*, unfortunately.

In 1903, the Government of Nova Scotia published a pamphlet on "Deep Gold Mining," by Mr. Faribault; this was in connection with an Act of Parliament intended to encourage further exploration by granting money in aid of shaft-sinking. The author's recommendations have been allowed to carry great weight, for the reason that he has accomplished a large amount of most useful work in the surveying and mapping of the gold-fields of the Province. Unfortunately the stratigraphical geologist of great ability has been incapacitated for such a task by being unacquainted with the realities of gold mining in other regions. Mr. Faribault writes as one intimately acquainted with the mines of Nova Scotia, but unfamiliar with the many and varied aspects of ore deposition elsewhere. He rides his hobby hard, and his steed appears neither to shy at the facts of experience nor to be affrighted by the sweeping statements of the rider. In this Government pamphlet he summarizes his views thus:

"The knowledge now gained by a detailed survey of the principal gold districts of Nova Scotia proves conclusively: That the veins which coincide with the stratification and outcrop at the surface are the remnants of north or south legs of superimposed 'saddle-veins' occuring on anticlinal folds, the apices of which have been truncated by extensive denudation.

That these saddle-veins are underlaid by a succession of other superimposed saddle-veins, which do not outcrop at the surface, but occur deeper down on the axis-plane of the anticlinal folds.

That all the mining done for the last 40 years has been confined to the saddle-veins outcropping at the surface, and the richest and most workable portions of thse are now mostly exhausted. It is therefore desirable that the succession of underlying saddle-veins should be developed in depth, as it affords an extensive field for deep gold mining.

From the analogy of the gold-bearing saddle-reefs of Bendigo, Australia, occurring in a similar manner and profitably operated to depths reaching 4,000 ft., it may be inferred that the Nova Scotia underlying saddle-veins will be found as large in size and as rich in gold as those cropping at the surface.

It is difficulty, however, to induce capitalists to invest money in such extensive mining developments in Nova Scotia, unless similar undertakings have already proved successful in actual practice. It is, therefore, very gratifying to know that the recommendations of the Geological Survey have already been put into practice at the Doliver Mountain, Richardson, Blue Nose, and Dufferin mines; and although the developments are as yet limited, the results obtained are most satisfactory and conclusive, and testify to the accuracy and value of the work done by the Survey. They prove that auriferous saddle-veins may be found to recur underneath one another to even greater depths, and in much closer succession than in Australia, and what has been accomplished at these mines can also be done in many other districts in the Province where the conditions are favourable."

It would be difficult to place in more compact form so many general statements the truth of which required proof at present not available. During the seven years that have elapsed since these confident forecasts were made, the four mines that were supposed "to testify to the accuracy" of such a geological diagnosis of Nova Scotia have failed, three of them miserably. "The developments" were "conclusive," indeed, but in a manner far different from what was expected on the basis of theories predicating a succesion of profitable saddle formations, for even an exploration limited in depth to three or four hundred feet sufficed to indicate that "the auriferous saddle-veins" *do not* "recur underneath one another to even greater depth than in Australia," that is, if "auriferous" bear any relation to the economics of mining.

Mr. Faribault refers to large lodes as preferable for deep mining. He says:

"It is acknowledged by the best authorities that the development of the goldfields in Nova Scotia has been retarded by the persistence of the prospector in neglecting for years the problem of large supplies of low-grade ore in favour of isolated rich veins. It is believed that the districts presenting the largest workable saddle-veins offer the best prospects for permanent and deep mining, and should receive the preference. The deepest mines in the Australian goldfields are operated on the largest saddle-reefs."

Of course, the prospector seeks for ore that is profitable, and, like a sensible man, he neglects the opportunity to solve a geological problem. An "isolated rich vein" may yield bigger dividends than "a large supply of low-grade ore." In all talk of this kind there is a lamentable confusion between quartz and

ore. The miner wants gold, not silica. The deepest mines in Australia were sunk to exploit profitable lodes, the ability to yield a profit being dependent on the two factors of size and richness. Many large bodies of quartz, at Bendigo and Ballarat, for example, have not been exploited because, after trial, they were found not to contain the proportion of gold required for a profitable mining operation. This idea of size, when divorced from a definite knowledge of richness, has been the cause of much foolish work in Nova Scotia, as in other countries. It may be a stimulant to flamboyant finance, but is not a basis for sound business. The "best authorities" who advocated the grandiose exploitation of large bodies of quartz poor in gold, knew less of mining than the simple prospector who kept his eye on pay-ore, extracting it by aid of a windlass or a whim; while the big companies, led by pseudo-scientific advisers, erected expensive mills and sank deep shafts in the expectation of finding large bodies of ore, the existence of which was only an unsubstantiated surmise.

All rules for the development of a mine based merely on geological structure, without such knowledge as comes from careful sampling and assaying, are worse than futile. It has been said, by the Canadian geologist whom we have been quoting, that "underground developments on vertical folds will thus require to be less extensive and will cost much less than inclined folds, and they should generally receive the preference for deep mining." The experience of mining, which antedates the science of geology, has demonstrated that deep mining is remunerative only where profitable ore has been proved to persist sufficiently to warrant further exploration by vertical workings. The purpose of mining is not to elucidate theories but to make money. If the geologist will show the miner how to find ore, he will dig the necessary holes, but he cannot afford to do so for the purpose of ascertaining academic facts. Old mining is distinctly utilitarian and makes friends with young Geology only when the latter shows sympathy with the purpose of his labour. That sympathy American and Canadian geologists have tendered to a marked degree, and if in Europe geology still adopts toward

the miner a pose more polite than practical, it is no wonder that the economic development of the science remains relatively insignificant.

J. EDMUND WOODMAN.

Another recent student of the subject is Mr. J. Edmund Woodman, formerly Professor of Geology in Dalhousie University, Halifax. On May 18, 1903, he presented a paper on the Moose River district, and on March 13, 1905, another on the "Distribution of Bedded Leads in Relation to Mining Policy." Both of these were read before the Nova Scotia Institute of Science. He proposed the name of 'Meguma' for the gold-bearing series, and divided it into a lower quartzitic division called the 'Goldenville,' and an upper or black slate division called the 'Halifax.' In the first of these two papers Mr. Woodman uses the term 'crenulation' to label the barrel structure. He shows that the crenulation is not always parallel to the stratification. Even undoubted cross-veins will exhibit this structure, although less frequently than those of the bedded type. In the second paper he states that in the Nova Scotian gold region there are 26 well-marked anticlinal crests, and exactly one-half of them show domes that have been tested by mining. Any one anticline, owing to cross-folds, may have several domes, but five is the largest known number on the same anticline. He states that only "one or two cases of gold-bearing bedded veins are so far known to exist in the trough of a syncline; and from the mechanics of the mountain-building and attendant vein phenomena, it is not to be expected that such deposits will occur along the synclinal axes to any extent." Hence "it is probably safe to neglect these folds entirely in exploring for new deposits." He emphasizes the association of gold-bearing quartz with the slate, and asserts that "no prospector wastes his time on country definitely known to be all whin." His use of the term 'whin' for quartzite is regrettable, especially as he refers to the fact that this word "was originally employed by Hutton, in Scotland, to designate certain sheets of trap, and in Cornwall still has a similar meaning." But this lapse need not detract from the undoubted value of his observations. For instance, he

makes the important note that the most violent folding takes place where the largest proportion of slate exists. There also the gold-bearing quartz veins are most plentiful. "If one goes out from the centre of a dome, he will proceed from a part in which outcrops and underground cross-cuts show a definite alternation of slate and quartzite beds, rather suddenly into a region in which little, if any, slate is to be found. This is a typical condition."

When, however, Mr. Woodman begins to apply his accurate geological observation to the furtherance of mining, he also (like Mr. Faribault) misses the one economic essential, namely, that mining operations must tend to be profitable, first, last, and all the time. He presents some "facts" to encourage the miner:

> "First, while there is an undoubted downward limit to the zone of leads which could be cut by a shaft sunk on the apex of a dome, we have no evidence that in any given district it is within the range of moderately deep mining, or that many valuable saddles may not be cut by such a shaft. The experiment has never been seriously tried. Second, while a very definite surface lateral extent is known for each true dome, there is many a district in which thre are enough paying belts to keep one or a very few large plants for more years than any of us will see. Third, while there is a definite downward limit to each leg of a saddle, at which the vein dies out, it has yet to be shown that anyone has reached that limit in a characteristic case."

Here, as in the case of Mr. Faribault, the scientist who applies geology to mining ought to be assisted by a sampler and assayer. No new deep shaft is necessary to prove that the profitably gold-bearing veins of Nova Scotia do not persist. Shallow mining to three or four hundred feet vertically has sufficed to ascertain that fact. The "experiment," as recommended by Mr. Faribault, was tried at the Blue Nose mine, at Goldenville, and it failed utterly. I venture to deny that "there is many a district in which there are enough paying belts to keep one or a very few large plants for more years than any of us will see." Yes, breaking stone for roads, but not winning gold profitably for the shareholders whose money was subscribed for the erection of the large plant. It indicates obtuseness to unpleasant realities to assert that "it has yet to be shown that anyone has reached the downward limit to the leg of a saddle," if Mr. Woodman is referring to a leg or quartz vein that is profitably gold-bearing. Certainly those of us who are engineers would

not urge the miner to follow the leg of a saddle for the sake of white quartz. Perhaps I speak roughly, but I do so in the interest of ascertainable knowledge. Spencer said that Huxley's idea of a tragedy was a beautiful theory killed by an ugly fact. Assuredly facts, ugly from one point of view, have massacred these theories of visionary geologists, who confuse the making of holes in the ground with mining, and the persistence of quartz with the continuity of gold-bearing ore.

CONCLUSION.

The foregoing citations from writers who examined the same region at successive intervals during fifty years is interesting as illustrating the growth of geologic thought. They serve to remind us how young the science is, and how infantile is that branch of it applied to the search for valuable ores. Errors in petrography were natural before the miscroscope was introduced, and mistakes in chemistry were not surprising before laboratories became easily accessible, but it is apparent that the worst errors are not caused by the lack of apparatus or other artificial aids, but by careless observation and reckless generalization. Keen eyes and a logical mind enabled several of the older investigators to arrive at remarkably correct inferences, while the multiplicity of instruments has not availed to prevent some of their successors from gross blunders. The general trend has been to discard catastrophic ideas and to apply the principles first enunciated by Lyell in 1830. The history of geologic thought as regards the Nova Scotian goldfields, as elsewhere, indicates a growing disposition to judge the unknown by the known, and the past by the present, with due allowance for varying conditions. Geology has become less visionary, while appealing no less to the constructive imagination. Knowledge does not kill theory, it serves but to discipline. If geology has so often failed to guide the miner in his groping underground, it has been because the science was allowed to drift too far from the safe anchorage of fact. All gold-bearing quartz is not ore, and every hole in the ground is not a mine.

DISCUSSION.

MR. J. E. HARDMAN:—My absence from the gold fields of Nova Scotia for the last fifteen or sixteen years almost precludes me from attempting to discuss, or in any way criticize, the admirable paper that Mr. Rickard has just summarized. As one who spent some ten or eleven years in Nova Scotia, I hope Mr. Rickard will allow me to say that I am in accordance as a whole with his views. He has, however, in his summary of his paper evaded the point which most of us (who have been in Nova Scotia) are so very anxious to have determined—he has made no predictions.

In 1905, the Government of Nova Scotia retained the services of Mr. Rickard, that he might advise as to whether the declining industry could be revived and made continuously profitable, or, at any rate, be prevented from declining further. I have not yet, and I do not think anybody else yet, has seen the report which he made to the Government of Nova Scotia on that occasion. Doubtless, he expressed a valuable opinion in that document. I admire his discretion, but I am not altogether satisfied that he should allow the present opportunity to pass without informing us of the conclusions at which he has arrived concerning the mining possibilities. That is the only criticism I have to make. Mr. Rickard's theory in regard to the 'barrel structure' is certainly a noval one and very worthy of credence; the point, however, to those men who have mined in Nova Scotia and those who perhaps are now mining there, is the dollar and cent question of whether values are going to continue. It is true that there is a vast difference "between a hole in the ground and a mine," and there is also a vast difference between a quartz lead and a pay vein. As to what he did say in 1905 as to the future possibilities of the gold fields of Nova Scotia, I think, as an engineer speaking on behalf of engineers, that we are far more interested in knowing if we are going to get gold values below 500 feet than we are in the matter of whether the sharp corners have been worn off to produce the celebrated barrel structure. I do not think many engineers will disagree with the statement that what we are here for is to know how we can make a dollar without it

costing us a dollar and two cents. That is really the problem in Nova Scotia:—is a gross value to be obtained sufficient to pay the cost of extraction to yield to the owner (or manipulator) a reasonable profit upon such investment? This is not, as I said before and I want to again disclaim it—this is not criticism of Mr. Rickard's paper, but his paper bears upon this important question. These gold fields have been worked continuously for 50 years; a certain amount of profit has been made out of them, and the question that I (and every other observant mining engineer) have to ask is—is it going to be profitable field for mining in the future?

MR. F. H. SEXTON:—Mr. Rickard's paper on the "Domes of Nova Scotia" will be read with much interest in that province. The author collected the data while making a report to the Nova Scotia Government in 1905 on the similarity of this gold field and that of Bendigo, Australia, and also on the probabilities of profitable gold mining to a depth of 2,000 or 3,000 feet. Mr. Rickard came to Nova Scotia with an intimate knowledge of the geological conditions and mining history of Bendigo, as well as an extensive mining experience in other parts of the world. Mr. Rickard was eminently qualified for the undertaking. The gold mining industry in the province had been steadily declining for a number of years. Efforts had been made previous to 1905 to stimulate deep gold mining by offering Government subsidy to companies who would undertake mining development to a depth of 2,000 feet in certain gold districts, if the mining project met with the endorsement of the engineering advisers to the Government. No appropriations in this direction had been made up to the date of Mr. Rickard's arrival.

I had the pleasure of accompanying Mr. Rickard on several of his preliminary trips to the gold fields of Nova Scotia, and was greatly impressed with his power of quick, accurate observation and detailed knowledge of geological and mining conditions in other parts of the world.

When Mr. Rickard first observed the curious 'barrel' structure that occurs in so many of the gold mines in Nova Scotia, he rendered the most plausible explanation of this

phenomenon that had been advanced up to that time. He made an important discovery of gold in a tongue of granite adjacent to a gold-bearing vein in the district of Forest Hills, and thus offered almost incontrovertible evidence of the age of the enrichment of the quartz veins, besides making a valuable contribution toward the theory that the granite was the original source of the gold.

Mr. Rickard did much to disillusionize the people in Nova Scotia concerning the profits of deep mining in Bendigo below the 2,000-foot level. His intimate knowledge of the mining developments and operations in Australia in this connection was invaluable. He pointed out that the financial returns from mining gold ore below the 2,000-foot level, although it has been carried out successfully in a few places, were not as great, in most cases, as the operations to a lesser depth. That information has had a beneficial effect in Nova Scotia, and to-day the gold miners do not talk very much about mining to a depth of more than 1,000 feet.

Many of the gold miners in the province have shifted their basis of thinking or, rather, hoping, that the veins could be profitably exploited to depths of 2,000 feet or more, and have now taken new heart in Mr. Rickard's prophecy that there was probably a bright future for these gold fields in applying the methods of the past to the lateral development of the gold-bearing veins instead of continuing operations to a greater depth than had theretofore been worked.

The report of Mr. Rickard to the Government of Nova Scotia has not been suppressed. Any man who came to the province intending to make any financial investment in gold mining has been accorded permission to read the report on request. Any man in the province who had any pecuniary interest in the gold mining industry has also had access to the report, if he desired it. Many men have perused the report. As yet the report has not been published for free distribution.

I am very glad that Mr. Rickard has paid a tribute to the work of Mr. E. R. Faribault of the Canadian Geological Survey for his work in the Nova Scotian gold fields. The people in the province hold Mr. Faribault in the highest esteem. For over

twenty years Mr. Faribault has given the whole of his energy to recording the geological occurrence of the gold veins, the limits of the pay chutes and all the invaluable data as to the depths of shafts and extent of the workings in these veins. Mr. Faribault has also prepared a wonderful series of large-scale, accurate maps of practically all of the many gold districts. These have been of inestimable value in the past and will serve as the basis of future mining operations.

I can contribute nothing in this discussion to the theory advanced by Mr. Rickard as to the formation of the crenulated structure of many of the quartz veins in Nova Scotia, because I am convinced that this is the right solution of the problem.

MR. WALDEMAR LINDGREN:—I am very glad indeed to have heard Mr. Rickard's interesting paper, and I am especially pleased that he has ascertained that the auriferous veins of Nova Scotia are younger than the granite because that region has been always upheld as a region where the theory that attributed the veins to the granite intrusion was not applicable.

Now, there is only one point on which I desire enlightenment, namely, that respecting the various ages of gold deposition. I know Mr. Rickard has emphasized the same view in his paper on Bendigo. I have been in Bendigo, but I confess I could not find very much evidence of more than one epoch, and that rather a short one. I would like to know if there is any definite evidence in Nova Scotia of anything like this, because, to my mind, the deposition of gold took place in a short and transient epoch which followed shortly after the intrusion.

MR. RICKARD:—I am glad to respond to the request of Mr. Hardman. I may say that Mr. Sexton has pretty well let the cat out of the bag. Although I am an Englishman, I have a little sense of humour, and this little episode, of my report on Nova Scotia, has as much humour as science in it, I think. I went up there, of course, in perfect good faith. Mr. Murray, the Premier, and the other gentlemen were all most kind to me, and the whole inspection was an incident to which I now look back with great pleasure. I wrote the report, fortunately, just before the San Francisco earthquake and fire, otherwise it would have been burned, but when it reached the authorities

at Halifax they delayed publication, and said something about an earthquake and a fire. It was sent before that. Then they said that they were expecting some further information, with other excuses, until I had to write, saying that while I quite appreciated their dilemma and I did not mind exactly what they said, yet if they went too far it might be necessary to contradict them, and that might seem discourteous, and I would be sorry to do so. This thing went on for some time. Finally, Mr. Murray, in Parliament, was asked about it, and he got up and made a speech, which was so long that he might just as well have read the whole report. The report is brief. The pith of it was practically given by Mr. Sexton, and it was this: that I found the deposits were of such a character that they did not lend themselves to the flamboyant operations of capitalists who expected to put up large plants and operate on a big scale, but the lodes were of such a character as to justify the Government in giving aid to the working miners and tributors, who are really the only people who have done any good in Nova Scotia. That was the report, and I regret to believe that it has proved true.

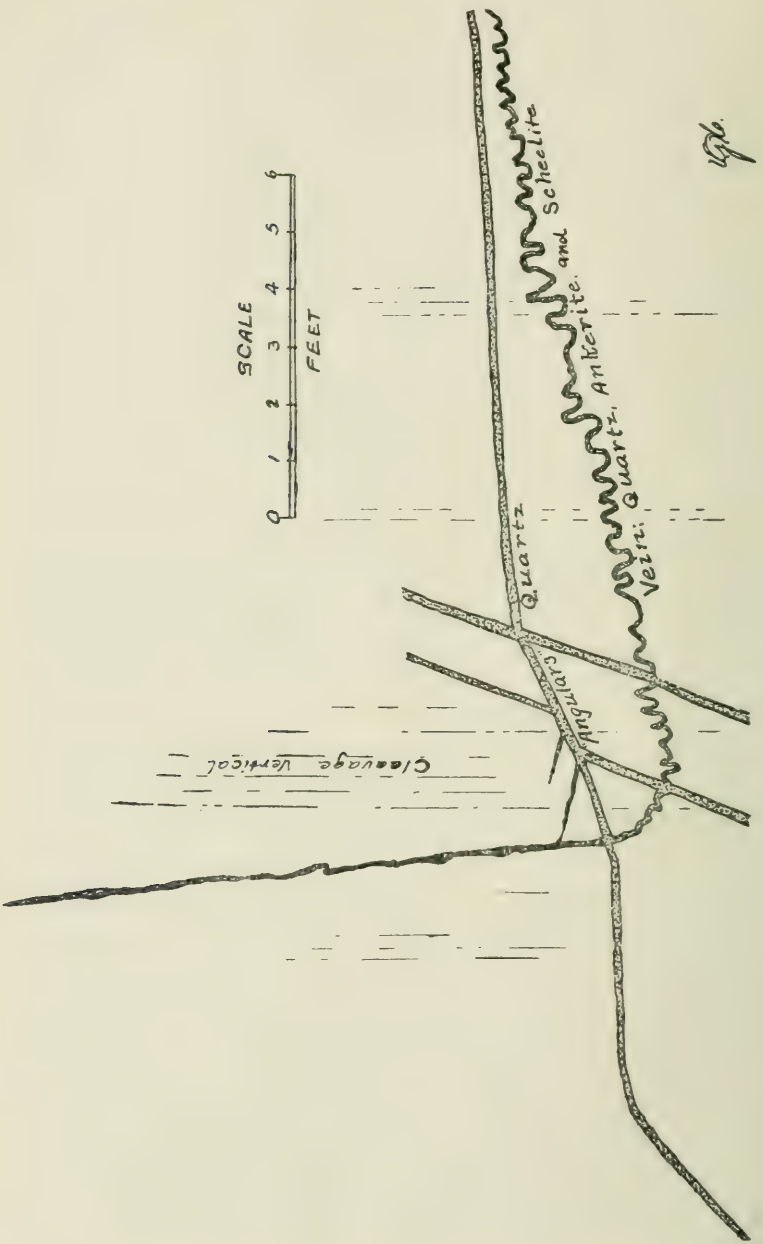
In regard to the question kindly put by Mr. Lindgren, I know that he holds, and I know that he has demonstrated, that in several districts the deposition of gold in lodes is confined geologically to a short period of time. In the case of these deposits in Nova Scotia the deposition was in the early Devonian, but I hold—much more as a mining engineer than a geologist, because among mining engineers I am a geologist, and among geologists I am a mining engineer—that the great point is not so much the age or the period during which gold is deposited, but the period during which it was deposited in the particular place where the miner now finds it. The process, I believe, began, or will begin, when it is first brought within reach of the circulating waters of the outer crust of the earth.

MR. VICTOR G. HILLS, Denver, Colorado. (Communication to the Secretary): In my original paper, "The Scheelite Deposits of Nova Scotia," I briefly noted two different theories which are advanced to explain the wonderful 'barrel' formation of the veins of Nova Scotia. We all now agree that they were

not deposited with the sediments as one of the original series; also that they are not explained as a replacement of calcite veins. This brings us to the point of disagreement, viz., were these corrugated, crumpled, or 'barrel veins' of quartz originally formed before or after the folding of the strata? All will recognize the truth and force of Mr. Rickard's statement that there are no "full-stops" in the geologic record and the disagreement might be more specifically stated in this way: Is the peculiar 'barrel' formation due mainly to the crumpling of veins originally deposited as comparatively simple, regular, veins during the earlier period of the folding process; or is it due to chemical action and deposition in zigzag fractures formed when the folding was nearly in its present shape?

Mr. Rickard's view seems virtually to rest on the statement that these veins cut across the bedding planes. This I regard generally as a mistake in the fact, but granting they do, in exceptional instances, that, it seems to me, does not establish his theory.

My view is that there are two systems of quartz veins: the older being the intercalated series developed during the earlier stages of the folding process as substantially horizontal interbedded veins. These were not continuous as individual veins throughout the extent of the sedimentaries, but were pancake-like lenses of substantially uniform thickness for a considerable extent, occasionally, perhaps, cutting across the strata. Afterwards these became crumpled in the soft slate by the sliding movement of the harder quartzites in the process of folding; thus making them the result of a compound folding which produces the wonderful serpentine appearance in cross-section. The other series of quartz veins is represented by the cross-veins, 'angulars' and spurs which were formed much later, after the folding was substantially completed.


SCALE
0 1 2 3 4 5 6
FEET
Cleavage Vertical
Quartz
Angular
Veins Quartz, Ankerite and Scheelite
Fig. A

The distinction between the earlier and the later veins is not readily seen in all cases, and frequently it is most difficult to identify and trace the sedimentary strata; hence arises some of the disagreement. The two systems of veins sometimes inter-

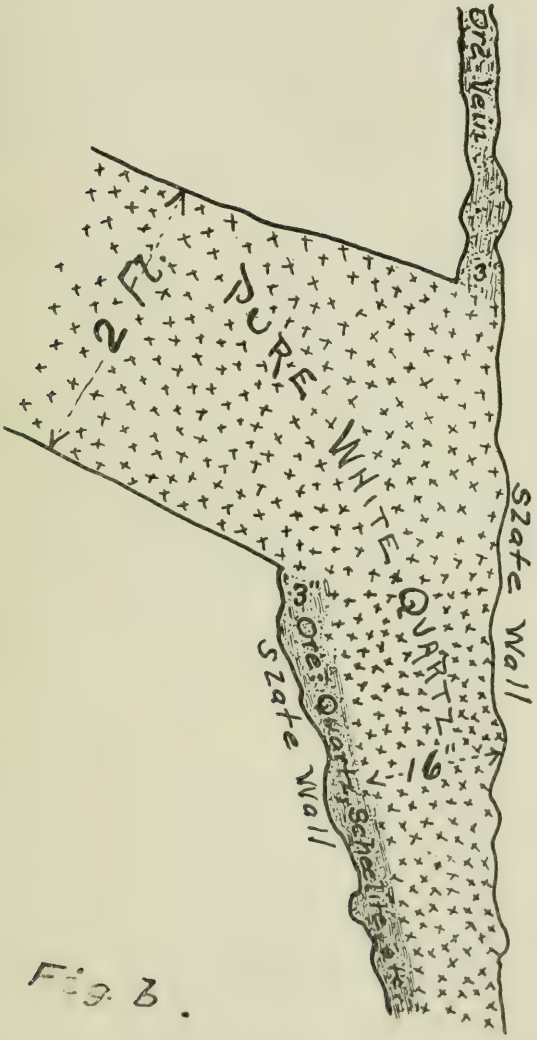


Fig. B

mingle in such a form as to confuse and readily mislead the observer. Figs. b. and c. show cases where the 'angulars' have broken into, and followed for a distance, the pre-existing intercalated veins. In such cases the blending of the two is frequently so thorough that only the most careful observation discovers the truth. Thus Fig. b. would not show the different ages of the veins except for the distinct ore character of the earlier vein. The 'angulars' do not usually follow the intercalated veins far: they seem to be essentially a cross-fracture system and, usually, take to the intercalated veins or the slate belts only for short distances in the form of spurs. (See Fig. c.)

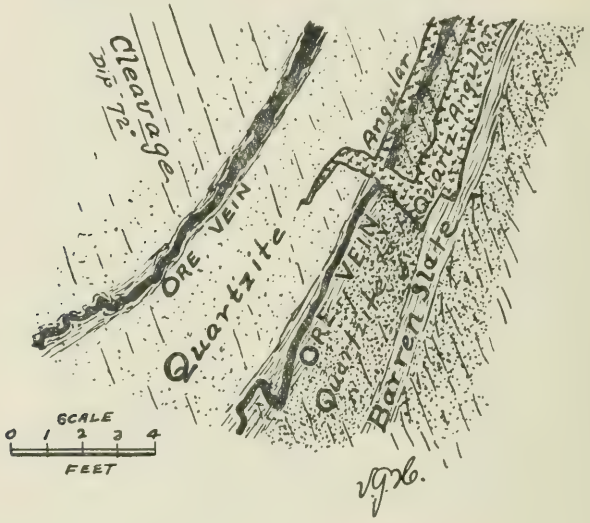


Fig. C

Fig. a. shows an old crenulated vein at its synclynal turn and later 'angulars.' Note the straight lines and independent courses of the latter showing that the fractures were made after the folding was substantially completed. Mr. Rickard has not failed to note something of this formation, for he says, referring to his photograph No. 22, "It is evidently crossed by quartz stringers of later origin." In places the cleavage is so intensely manifested as to almost entirely obscure the original stratification and sometimes makes it difficult to distinguish locally be-

tween the quartzite and the slate, requiring a close study of the formation in other nearby workings before the strata can be traced. Thus in Figs. 3 and 4 of my original paper the cleavage is prominent and the stratification is indistinguishable.

One fact tending to show two series of veins of distinctly different ages at Moose River is that the corrugated veins contain quartz, scheelite, lime spar, and arsenopyrite; while the cross-veins, including the 'angulars' and spurs, consist of pure quartz only. (See Fig. b.)

As evidence that these crenulated veins are not the filling of fissures made in their present forms, I note the absence of the customary comb structure which is so common where quartz fills an open fissure. Even where there is complete filling, outlines of the crystal forms may be discerned. However, this is only negative evidence. Mr. Woodman's statement that "the evidence is of continual accretion inward, on both sides," is quoted in my original paper; but as regards the earlier series of veins my observation is exactly to the contrary. During a year's work I never observed a sign of comb structure or other evidence of "accretion inward" in the corrugated veins, and the appearance of such formation in the cross-veins of course has no bearing on the case if these are of later origin.

Paralleling serpentine veins such as shown in Mr. Rickard's photographs 12, 13, and 14, seem to speak emphatically in favour of formation before folding. And in case of the minute veinlets, about one-sixteenth of an inch thick, which are a common occurrence and frequently found substantially paralleling the main corrugated vein, such as seen above the main vein in my photographs Figs. 3 and 4 before noted, it seems difficult to imagine them as other than segregation veins formed before folding.

The crenulated form on the synclines as well as on the anticlines is another point against the fissure filled theory, since dead weight would work against the maintenance of such an opening while the arch might support one on the anticline. This feature is noted by Mr. Rickard.

The curving of the slate laminæ to parallel the turns in the quartz veins, which fact is recognizd by Woodman, does not

seem to be explained in any satisfactory manner other than the slow crumpling of the quartz under great pressure.

The zigzag formation described by Mr. Rickard seems to me to fail in several particulars to explain these corrugated veins. The tendency of a fissure to take a zigzag course on account of different kinds of rock traversed, or by deflection caused by pre-existing fissures, or cleavage, is common and well known. However, there is a natural physical limit to the angle of deflection in such a course. That such angles should reach or approximate 90° is unlikely and certainly unusual; or in any event the sum of any two consecutive angles on the same side of the line should exceed 180°. At least it may be said that a fissure would never break the longer path and leave the shorter distance unbroken in the same direction and in the same kind of rock, as seen in the repeated horseshoe curves. See my photographs 3 and 4 accompanying my paper and Nos. 4, 5, 8, and 12 of Mr. Rickard's paper. To me it is unthinkable that any force or combination of forces could open fissures having every course within 360° before advancing a single yard. The same force which would open one part of such a fissure would close another part. At most, any such tortuous opening could not be expected to show such a remarkable regularity in thickness.

Chemical action may readily account for cutting off the corners and rounding the inside of the turns, but I do not see how it would operate to make a rounded surface at the exterior angles. If it did thus act the veins should be much thicker on sharp turns, which is not frequently the case; and where such thickening is shown it may as well be attributed to the pressure due to folding. The most that could be expected from a zigzag fissure following a curve around an anticline or a syncline would be a sort of saw-tooth break, like Mr. Rickard's Figs. L, M, N, and O, and chemical action rounding such points would never modify this form into such horseshoe curves as we find. It would tend to lessen rather than to accentuate the crookedness of these veins.

Sir William Dawson, in 1866, says:—

"The arrangement indicates great lateral pressure; and, which is of more importance, proves conclusively that the quartz veins are contemporaneous with the folding of the rock, since they have perfectly followed its

folds without fracture. That the auriferous quartz veins are not bede is evident from the manner in which they send off branches into the neighbouring rock, as well as from their own crystaline structure and the character of the imbedded minerals. They are undoubtedly true veins, but not veins formed by fracture of the containing rocks when in a hard and metamorphosed state. They have been formed and filled in the very act of the contortion and altering of the strata, and are thus of the nature of segregation veins, gradually formed as the spaces containing beds were bent without fracture and with but little crushing.''

I first saw this quotation in Mr. Rickard's paper after having formed my own opinion and written my original article. It seems to me that Dawson's idea corresponds substantially with what I have outlined. In fact, we do not differ in any particular except that he did not, apparently, recognize the spurs as of a later series than the intercalated veins. And his observation was certainly contrary to those of Rickard and Woodman.

The photographs tell the story more forcibly than words. My photographs, and probably some of the others, need this explanation. The quartz being much harder than the slate, it is so broken out in blocks that some places are nearer and some farther from the camera than the enclosing slate. This, with the necessary wide angle at the lense, makes shadows and otherwise gives the appearance of breaks and narrow places in the vein which do not exist.

My drawings a, b, and c are from places where it was impossible to secure photographs; but the original sketches were made on the ground from actual measurements.

Taking the four photographs which Mr. Rickard refers to as showing the strata I note as follows:—

In the case of Nos. 9 and 17 I fail to see, either in the photographs or in the descriptions, that the veins do cross the strata: No. 9 seems to be a typical case of a crenulated vein in a bed of slate.

No. 15 is clearly a cross-vein but not a 'barrel vein' and hence not applicable to the discussion.

No. 13. Here I must accept the statement that the straight vein follows the bedding, though the photograph itself does not show it. Then I regard the 'small curly lead' as one of the rare cases where one of the earlier series of veins has transgressed the rule and was formed in a fracture crossing the strata and has been crumpled by the subsequent folding.

In Rickard's Fig J and photographs 6 and 9 I regard the simple quartz seam along the bedding plane as of the later age, introduced after the folding. This occurrence is rather unusual.

Where Mr. Rickard speaks of the great truths of geologic unrest and of the fact that these movements do not cease at a given moment I believe that I fully appreciate not only the beauty of the language, for which he is noted, but, as well, the sound geologic force of the thought. But the consideration of the eons of time, which no human mind can span but which are represented in such formations, supports the one theory as much as the other.

MR. T. A. RICKARD: I have read Mr. Hills' comment with interest. His observation of the scheelite veins is quite *à propos*, and his criticism is fair. I do not expect to "establish" my theory, it may not be correct; in any case, more evidence is required. What I have done is to point to certain observed facts, which render several older theories no longer tenable. I have cleared the ground for a theory that will stand the test of observation. Meanwhile I have suggested an explanation that meets the test of my own observations and that appears to be in accord with geological principles as ascertained in other regions.

Mr. Hills states that my explanation rests on "the statement that these veins cut across the bedding-planes." He forgets the relation of the pitch of the crenulations to the intersection of bedding and cleavage. That is a most significant fact. Incidentally, I note that in Mr. Hills' Fig. A, the scheelite vein is not crenulated, but follows a nearly straight line, so long as it is following the line of cleavage, but that it becomes crenulated immediately upon changing its direction to a line at right angles to the cleavage. I welcome this illustration.

Of course, the occurrence of quartz veins of different ages has been recognized. I gave a photograph from the Richardson mine as an illustration, and I drew attention to the conformable barren quartz seam that runs nearly parallel with the crenulated vein at Mt. Uniacke. Besides these there are the cross-veins or 'angulars,' which appear to have a close connection with the localization of ore-shoots. But this also has been discussed in my paper, with special reference to the Oldham mines. Mr. Hills refers to comb structure or 'crustification'; this is an interesting

point. I agree with him that this structure is rare, even if not absent, in the crenulated veins. But the filling of an "open fissure' by quarts is not within the purview of any explanation emanating from me. Such an assumption is not necessary, for my notion of the channels along which these quartz veins were deposited supposes only a fracture, marked by partings that may be discontinuous along a particular section but do afford a passage for the penetration of mineral solutions. Open fissures and crustification are uncommon phenomena, nor are they necessary to the precipitation of gold-bearing quartz. The parallelism of the serpentine veins need not, it appears to me, "speak emphatically in favour of formation before folding," because two or more fractures crossing the same cleavage, or alternation of texture, would be likely to behave similarly, creating a parallel structure. However, I do not wish to belittle the evidence proffered by Mr. Hills. It is indeed difficult to offer an explanation that fits all the facts, but I submit that even if only one authentic example were forthcoming of a crenulated vein crossing the bedding-planes, then any theory based on conformity must be rejected unreservedly. That, I believe, has been established by my paper.

CONTRIBUTED REMARKS ON "THE DOMES OF NOVA SCOTIA." TRANS. INSTITUTION OF MINING AND METALLURGY.

MR. W. F. A. THOMAE:—I was much interested in the quotation from Selwyn on p. 40: "In one instance, an auriferous quartz vein was found to pass gradually by the addition of felspar and mica into granite." This is a striking example of the close genetic connection of ore veins with igneous intrusions so ably advocated by J. F. Kemp. This relationship is seldom so apparent, and in the case of Nova Scotia the author states that the veins there penetrate the granite and maintain their identity, but not for long. Nevertheless, I am strongly of opinion that here also the gold quartz owes its existence to the granite intrusion.

The Australian case, just quoted, was apparently an instance of magmatic segregation during solidification of the magma, while, in Nova Scotia, the crust of the magma had

already solidified, and, in so doing, produced superficial cracks before pneumatolitic or aqueous deposition filled these with ore and extended into the country. But in either case the substance of the vein filling was derived, in the first instance, from the igneous magma. This is the role of the igneous rocks in vein formation, as I understand it.

C. R. Van Hise has stated his opinion as follows: "The greater number of ore deposits are the result of the work of underground water."*

This is not so much in conflict with the origin of ores, as propounded by J. H. L. Vogt, J. F. Kemp and others, as might appear at first sight.

While holding with the latter that igneous intrusions were the original sources of ores in by far the majority of cases, it is probable that frequently their ultimate deposition took place from water.

The apparent conflict is caused by none of these authorities sufficiently emphasizing the fact that no hard and fast line can be drawn between magmatic segregation, pneumatolitic and aqueous deposition.

The eminent Swedish physicist, Svante Arrhenius, quoted by Vogt, has clearly described how segregation from a molten magma is assisted by enclosed aqueous solutions. He says: "When the water content is considerable, the aqueous gas collects in larger volumes, and in these are concentrated the bodies which, at the existing temperature, are more soluble in water than in the silicate magma." "By reason of the greatly superior mobility of the aqueous solutions, as compared with the magma, these segregations may send out branches in the form of the finest apophyses." It is clear that this action is practically pneumatolitic deposition, so that this differs from magmatic segregation merely in degree of aqueous solution, and the one must merge into the other.

Now if these aqueous segregations come in contact with the ground-water circulation, they are bound to amalgamate with it, and deposition from underground water takes place. Viewed in this light, Van Hise's statement is possibly correct,

*Trans. Amer. Inst. Min. Eng., vol. xxx, p. 30.

subject to the actual extent of ground-water circulation, but the igneous magmas still remain the original source of the ores, as so clearly expounded by Vogt.

It follows then, in all probability, that ores deposited within the reach of the ground-water circulation at the time of the igneous intrusion from which they sprang owe their existence to deposition from water, while those deposited beyond the reach of this water must be ascribed to magmatic merging into pneumatolitic segregation, which, it must be understood, resolves itself into deposition from water (as temperature and pressure decrease), with the only difference that this water has the same source as the ore. Deposition from ground water is therefore merely the result of a further dilution and distribution of these segregations, and the chief point at issue between the various authorities is the question of the degree and extent to which ground-water circulation may be assumed to exist. That it is quite so universal and far-reaching as Van Hise argues, may, I think with Kemp, be doubted.

As a consequence of this view of the merging of one mode of deposition into another, it would appear that you cannot differentiate between tin veins, silver-lead veins, gold veins, etc., as produced by different methods, because any one of them may represent any phase of the series, from magmatic segregation to deposition from ground-water, according to the physical conditions existing in each case. Much that has been controversial seems to me to be made clear by this view of ore deposition.

Take tin deposits, for example. At the magmatic-pneumatolitic end of the series we may instance the pipes in granite of the Waterberg district in the Transvaal, while the silver-tin veins of Bolivia may merge into deposition from ground-water. In this connection the question suggests itself whether the change from tin ores to copper ores in Cornwall, and from tin to silver ores in Bolivia, is not due to a change from pneumatolitic or magmatic water to ground-water deposition, caused by the amalgamation of the rising pneumatolitic segregations with the ground-water circulation, in which case the region of change should indicate approximately the lower limit of the

ground-water. Take gold veins: from the case of magmatic segregation quoted from Selwyn, to the general quartz deposited from water, there is probably every gradation, certain phases of which may be represented by the Passagem lode in Brazil and the Alaskite veins described by Spurr, to mention only two examples.

The author's description of the origin of the 'barrel' structure is graphic, and leaps to the eye of common sense, if such an expression may be allowed.

There seems to be some mistake about the scale of the diagram, Fig. G. It does not harmonize with that of Fig. H, or with the figures referring to the Borden Lead, the fold being there given as 40 ft. across and 15 ft. vertical, which confirms the scale shown in Fig. H. only.

PROFESSOR HENRY LOUIS:—I am profoundly interested in Mr. Rickard's account of the 'barrel quartz.' of Nova Scotia, and am pleased to learn that there are still localities where this structure is visible. I had a good opportunity of studying this formation in 1877, and my field notes made at the time lie before me as I write. I have described the barrel quartz of the Waverley district in my (1896) edition of "Phillips' Ore Deposits," p. 154, and have given there also a section across the formation, copied from the rough sketch that I made on the spot in 1877. The mode of origin that I ascribed to it at the time, and still hold to be a probable one, is that the slate beds underwent a bending action that caused the strata to separate somewhat at the apices of the flexures, whilst the slate at the same time wrinkled or crumpled up under the combined action of bending and lateral pressure. Within the space thus formed, quartz and the accompanying minerals (gold, arsenical pyrites, iron pyrites, copper pyrites, zinc blende, galena, calcspar, etc.), were deposited from solution. In my field notes I have noted the occasional occurrence of fragments of the country rock in the quartz as evidence that these deposits are true veins. The remainder of my notes is transcribed almost literally in the book above referred to.

Somewhat similar corrugations, though often much more strongly marked, are to be found in many of the rocks of

North-western Norway, and are especially characteristic of the magnetic schists, e.g., at Lyd-Varanger. I have hazarded the conjecture that these violent foldings are due to pressure set up within the mass of the rock by the crystallizing out of the various minerals. I can see no other explanation than internal pressure that will account for the way in which these local flexures occur, whilst the general direction of stratification is unaltered. I refer to this formation here because it presents at first sight a very great likeness to the smaller occurrences of barrel quartz; though I believe the causes of the phenomena to be quite different in the two cases.

It may be worth while adding a few remarks upon the word 'whin,' on which Mr. Rickard is somewhat at fault; in one place he says it is used in Derbyshire, and later on he applies it to one particular sill in the North of England. The word 'whin' is never, as far as I know, used in Derbyshire, the local term there being 'toadstone,' which, as is well known, is a corruption of the old German phrase 'Todt-stein.'*

The word 'whin' is used throughout Durham, Northumberland and Scotland, being generally applied to any hard, tough, dark-coloured basic igneous rock; it is, however, also used very generally by drillers, sinkers, etc., to designate any unusually hard stratified rock, and it is obviously in this sense that it has been applied to the quartzite in Nova Scotia. I take it that Mr. Rickard is unaware of this application of the word, or he would hardly have looked upon its use as implying an error as to the mode of origin of the rock. It is important to bear in mind that 'whin' is applied in North Britain to hard, stratified rocks, such, usually, as hard sandstone, ganister, etc., as well as to igneous rocks; the latter are often distinguished as 'whin dyke' or 'whin roll,' so that in a section, say, of a drift recorded by a North-country man, the words 'whin' and 'whin roll' may both occur, the former meaning a stratified and the latter an igneous rock.

MR. T. A. RICKARD:—Replying to Professor Louis, I had not read his description of the barrel structure, as I did not possess the revised edition of "Phillips' Ore Deposits," having

*Phillips & Louis, "Ore Deposits," p. 110.

no liking for books that are patched posthumously. If I had seen the Professor's diagnosis of this structure, I might have foreborn to cite it, for it is unquestionably incorrect. As already stated in my paper, some of the barrel veins cross the bedding-planes of the slate and quartzite. This observation has also been made by Professor Woodman. It kills the theory that the quartz fills spaces between the flexures of the strata.

In regard to 'whin' and my objection to the use of the term for quartzite: it may be that "drillers, sinkers, etc.," employ it, but I find that persons more careful in the use of scientific terms do not use it as a synonym for a hard sedimentary rock. Geikie uses the term once in his text-book, in stating that "the most remarkable example of an intrusive sheet is the whin sill of Northumberland."* Here, of course, it refers to an irruptive igneous rock. For the provincialisms of the illiterate I have no regard; it is my constant effort to standardize the terms employed by those who use our language in a discriminating manner.

Mr. Thomae's comments are appreciated. The relation of the quartz veins to the granite was mentioned also by Mr. Frank Sexton, in his remarks made when the paper was presented. It has been assumed by earlier investigators that the granite was extruded after the gold veins had been formed, and that the enrichment of the quartz bears no relation to the existence of the granite. At Forest Hill, near the Strathcona Mine, a narrow apophysis or thread-like protrusion of granite is seen (along the surface of the ground) between the bedding-planes of the slate. It is bordered by small veins of quartz, apparently intermittent, but actually continuous, although dwindling in places from a maximum of 2½ in. to a mere thread. This quartz shows mica, while the granite is quartzified, so that they tend to resemble each other; in some spots it is difficult to differentiate, at others the distinction is readily obvious. I detected free gold both at A, in the quartz next to the granite, and in B, in quartz traversing slate, as is shown on the accompanying sketch, made on August 31st, 1905. The quartz extends into the granite in places and is evidently of

*"Text-book of Geology," 1893, p. 575.

B
A
PLAN
SECTION
GRANITE
QUARTZ
SLATE

later origin. Other structural conditions also indicate that the quartz was formed after the granite, for the evidence does not favour the idea that the granite penetrated pre-existing quartz and split a small vein so as to divide it equally. The order of formation obviously was: slate, granite, quartz, gold. Thus the precipitation of the gold was probably a sequel to the thermal activity that ensued upon the irruption of the granite.

Elsewhere in the vicinity the granite contains quartz identical in appearance with that of the bordering veins, and this quartz in the granite exhibits a tendency to form a connected series of impregnations such as would constitute a vein.

According to J. C. McDonald, of Forest Hill, a vein 5 ft. wide, containing chalcopyrite and mispickel, traverses the granite at Country Harbour.

THE SCHEELITE DEPOSITS OF NOVA SCOTIA.

By Victor G. Hills, Moose River Gold Mines, N.S.

(*Annual Meeting, Toronto,* 1912.)

Scheelite Camp is situated five miles northeast of Ship Harbour, Long Lake, and 34 miles by waggon-road from Stewiackem, the nearest railway station, in Halifax County. On Sheet No. 50 of the Geological Survey of Canada the position may be noted by the words "Numerous Quartz Veins Prospected" on the Moose River anticline. The words refer to old prospecting for gold. The scheelite deposits occur in veins of the same formation and character as the gold-bearing veins of the region. The Nova Scotia peninsula is occupied by granite and Lower Cambrian quartzites and slates. The striking characteristics of the veins is their similarity to the saddle reefs of Bendigo, Australia.* Thus, in both cases, the formation is quartzites and slates, much crumpled and folded; there is the same development of parallel anticlines in series; in both fields, the movements causing the folding appear to have a common origin with neighbouring intrusive-granite, while other points of similarity are: the metamorphism of the sedimentary rocks is dynamic; the metalliferous deposits are in quartz veins paralleling the original sediments and were folded with them; other lodes are found crossing or connecting the regular interbedded veins; the most common ore deposit is gold associated with arsenopyrite; and the ore-shoots usually parallel the folds.

The points of dissimilarity between the two regions are that the anticlines in Nova Scotia are from three to five miles apart, while in Australia they are only from a few hundred feet to one-fourth of a mile apart, and in Bendigo there is some show of igneous activity, while in Nova Scotia the metamorphism seems to be entirely dynamic.

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*T. A. Rickard, Trans. Am. Inst. of Min. Eng. Vol. xx., p. 463; also Vol. xxi., p. 686; also Vol. xxii., p. 289.

The Scheelite deposits are in the Moose River Gold Mining District, two miles to the west of the old gold mines and on the same anticline. Fig. 1 shows the plan of the veins at the

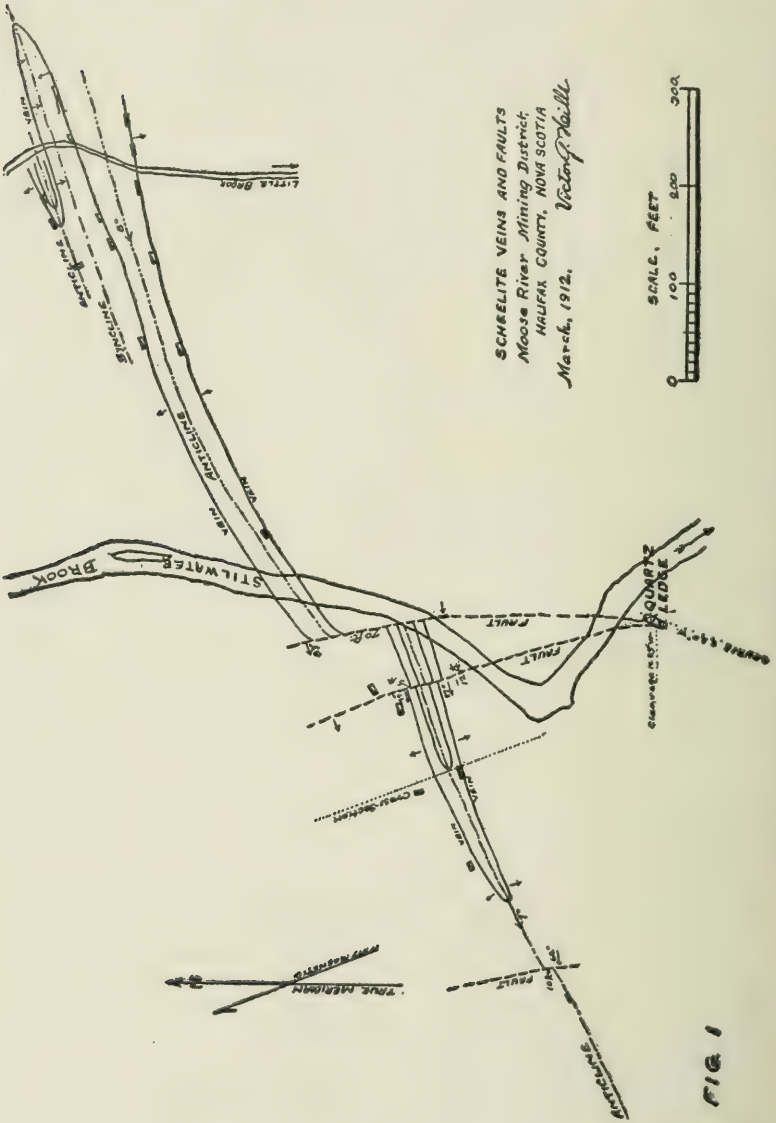


FIG. 1

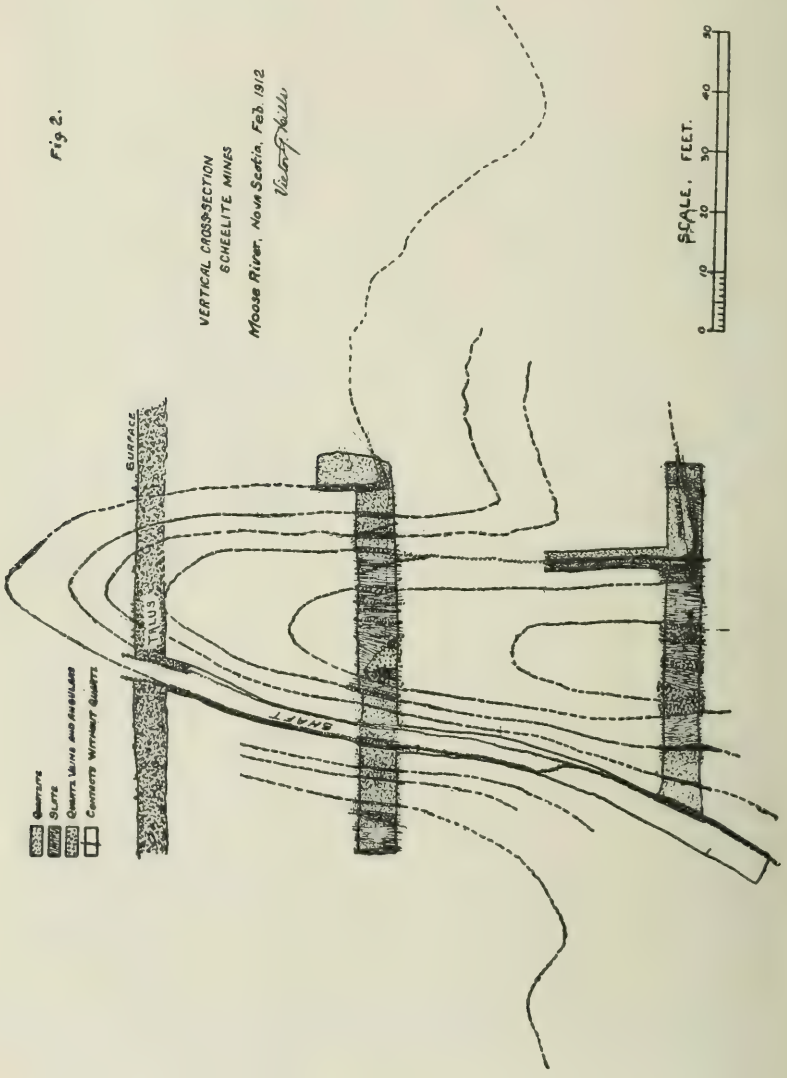
surface (the surface is practically level), and Fig. 2 is a vertical cross-section. The peculiar crumpled or corrugated form of the veins is unique and interesting. Fig. 3 is a photograph of a typical vein at its anticline, and Fig. 4 is a portion of the same vein on a larger scale. These show the vein in vertical cross-section. In Fig. 4, near the top, may be seen a parallel vein less than one-fourth of an inch thick, but having the same sinuous course.

Two explanations have been advanced to account for this exceeding sinuosity.* Woodman holds that it is certainly not due to sliding strata or to metasomatic replacement and believes that the sinuous courses shown represent the outlines of the fissures formed by the folding pressure which were afterward filled with quartz, and claims that "the evidence is of continual accretion inward, on both sides, as in other fissure veins and not from a central primary layer outward." In support of this theory is the fact that a deposit of quartz is the latest exhibition of the entire formation as shown by quartz veins cutting across the folded strata in such a form as to make it quite evident that they were formed after folding was substantially complete. Faribault,† on the other hand, maintains that the quartz veins were formed with the slate beds, being gradually deposited during the earlier period of metamorphism and deformed into these wrinkles by differential pressure, causing the slate to crush and buckle between sliding bands of harder quartzite. In support of this view is the fact that crystals of mispickel in the slate show emphatic deformation and shearing, and scales are found imbedded in the quartz, and the slaty cleavage often curves, paralleling the turns of the vein. My observation agrees with Faribault's, and in addition to the reasons mentioned by him I note the entire absence of comb structure or of drusy cavities in these veins and also that the sinuosities of the veins are often so pronounced as, it seems to me, to preclude the possibility of their formation

*Proc. Trans. Nova Scotia Inst. Sci. 1903. x., p. 67.

†On the Gold Measures of Nova Scotia and Deep Mining," Journal Canadian Mining Insitute. 1899. Vol. ii., pp. 119-129, and discussion on same. pp. 244-251.

as open crevices. The spurs or 'angulars,' which are quartz veins cutting across the bedding, seem to be of a later age than the interbedded or 'intercalated' veins. At Scheelite evidence of this is found in the condition that the veins following the



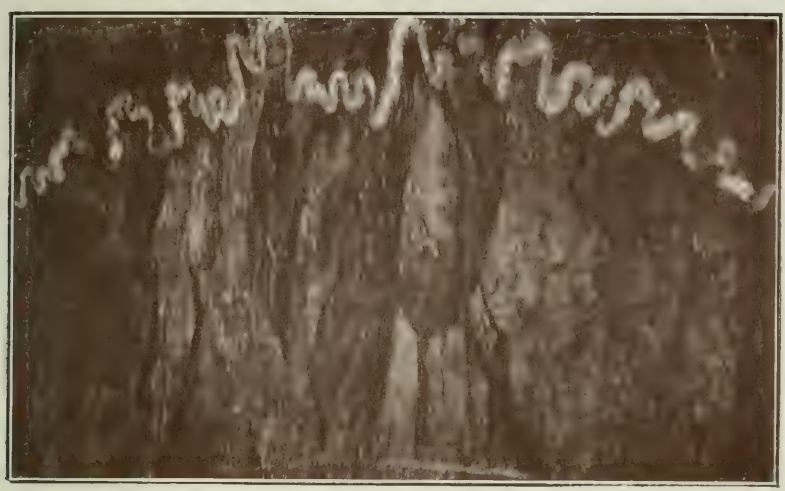


Plate III.

Plate IV.

Plate V.—Section of scheelite-bearing vein, showing the chief minerals: 1, quartz; 2, scheelite; 3, arsenopyite, and 4, slate.

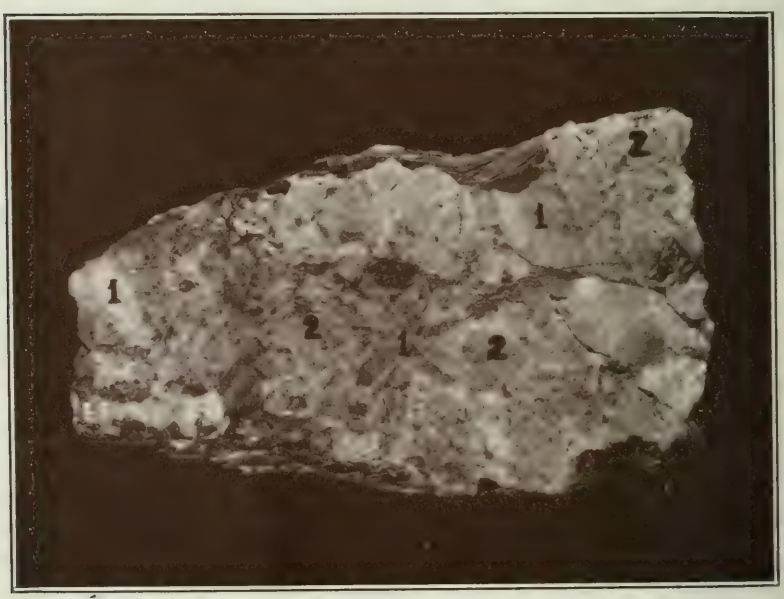


Plate VI.—Section of scheelite bearing vein, showing the breciation and subsequent quartz filling. 1, quartz; 2, scheelite.

bedding contain the four characteristic minerals of the camp: quartz, scheelite, mispickel and ankerite, while the 'angulars' consist of quartz only, and the other minerals are brecciated and the cracks filled with quartz. The cross-veins and spurs may have been subsequent even to the faults, mentioned later, but the evidence on this point is not clear.

The main anticline strikes S. 67° W. and has a pitch of about 7° to the west. There are secondary parallel anticlines. The dip of the veins is shown by the cross-section, Fig. 2. The folds in connection, with the pitch of the anticline, causes the strike of the veins to trace slender eliptical curves reversing between the anticlines and synclines. (See Fig. 1.) The veins are interbedded or intercalated and are usually in the slate rather than in the quartzite layers.

At Scheelite Camp three faults crossing the folds have been disclosed. The throws are from 10 to 70 feet (Fig. 1). The 70-ft. horizontal throw appears to have but slight vertical displacement. The second fault displaces 5 feet horizontal and 11 feet vertical. No scheelite or arsenopyrite has been found in the faults. The veins are numerous and small, usually from one to six inches, but sometimes widening to several feet near the anticlines and synclines. The scheelite ore-shoots are rather more regular and continuous than is the case in most of the tungsten deposits of the world, but are not so closely confined to the anticlines and synclines as are the gold deposits. The vein matter consists of quartz, ankerite, scheelite and arsenopyrite. There is also a little pyrite and calcite, while a few slender black tourmaline crystals are present in the quartz, in the calcite and in the scheelite. No gold, beyond a trace, has been found here, although it is of interest to note a little scheelite was found in the old gold mines at Moose River.

It is a remarkable fact that not a particle of wolframite, ferberite or hubnerite has ever been observed in these deposits. It seems certain that the scheelite and arsenopyrite were among the earliest minerals deposited, as they are frequently found brecciated, the cracks being filled with quartz, calcite and ankerite.

Although in Nova Scotia it would seem that these scheelite deposits are not directly traceable to an igneous source, nevertheless I should prefer to consider it probable that the granite is in place at no great depth beneath the present deposit.

Most of the tungsten deposits of the world occur in regions underlain by granite or porphyry. Walker,* in his report on "The Tungsten Ores of Canada," quoting from the "Records of the Geological Survey of India," shows a close geological resemblance between the occurrence of wolframite in Central India and the scheelite of Nova Scotia.

The scheelite deposits which I examined at Gardiner, Montana, are in regular quartz filled fissures in gneiss and schist. They are there found in a gold mine, the tungsten deposits being in the same veins but in separate ore-shoots from the gold values. The scheelite is the most friable of the four constituent minerals, and, therefore, little can be done in the direction of hand-sorting the ore. Concentration presents no unusual difficulties. The difference in specific gravity between the pyrite and the arsenopyrite is sufficient to throw most of the pyrite with the tailing from the concentrating tables; but the arsenopyrite, having the same density as the scheelite, they together form the raw concentrate which has to be roasted and treated with a magnetic separator. The new Wilfley revolving hearth furnace, roasting a single layer without stirring, is particularly adapted to the necessities of the case. A Ding Single Magnet Separator makes a very clean separation. The loss in slimes is not high as compared with slime losses in general, and not as high as is the case in the treatment of the black ores of Colorado. The ore dressing problem for these ores is worthy of a separate paper.

*Canadian Department of Mines Report No. 25. pp. 18-21.

LABOUR AND OTHER COSTS.

By J. D. Kendall, London, Eng.

The inconvenience of the practice of keeping the costs of work in money units only must have occurred to most engineers who have had experience in countries using different monetary standards and where the rates of wages, as well as the prices of materials, also differ. Even in the same country and in the same district costs prepared on a monetary basis become of little value, after the lapse of years, unless the rates of wages and the prices of materials, at the time to which the costs relate, are known. For commercial purposes the monetary element is, of course, necessary. But for technical purposes—as, for example, estimating the cost of opening up a new mine, or of some new work in a mine already opened up, it is quite unnecessary and often most inconvenient, until the final stage of the calculation is reached.

Thirty years ago, when the writer's practice in different parts of the world began, he found that considerable calculations were necessary to enable him to apply the rates of work gained in his previous practice in England to the frequently varying conditions met with abroad. He then commenced to prepare costs on the system of stating them in quantities of labour and material instead of money and it is this system he wishes to place before the Institute in the present communication. He has found it of rapid application and with a few necessary precautions quite reliable.

The amounts of materials used for the same class of work are the same everywhere, but the quantity of work of which men are capable varies in the same mine, as well as in different parts of the world. But engineers who are accustomed to deal with men will soon arrive at their comparative value. Sometimes

the difference in the amount of work done by men of different nationalities arises from a difference of method. For example, at a mine in the south of Spain with which the writer became connected about 23 years ago, plant and tools of primitive types were employed, with the result that a low output per man was obtained. Their methods were afterwards modernised and it was then admitted by English foremen that the Spaniards did as much work as Englishmen would have done in the same conditions. Some of the costs to be given in this paper were obtained at that mine, and the writer considers them average figures.

In some countries the amount of work men are capable of is reduced by an unreasoning objection, on the part of foremen, to contract work. In other countries, where contract work is general underground, the work that men can do is reduced either by their unions, or by a foolish practice, sometimes prevailing, of fixing prices so that men should not make above a certain wage per day. When a contract is let on this system—say for a month—if the price agreed upon is high, and the men make a large wage, the price is cut next month, and still further cut in the third month if the amount earned yields more than the management considers an average wage. Once men realise that their extra efforts are penalised in this way they hang back and work to the manager's average wage only, with the result that the working costs are ultimately increased.

Contracts with workmen, even for short periods, are sometimes very unsatisfactory, because they cannot afford to lose. As a consequence, if the price fixed for any work is too low to yield a living wage, they are obliged to recede from their contract. When prices are too high they hold on to the end. A much better system is the wage and bonus system, according to which a fair wage is given for time worked and in addition a substantial bonus to the leaders for all work done beyond a specified amount in a given time.

A few examples of costs in time and materials will now be given. They relate to a great variety of work and are derived from the writer's own experience. Much may be done to extend them in future. The Institute might decide to prepare a set of

such costs for each country and so render unnecessary the adjustments required with one set of figures only, such as those now submitted, which are mainly derived from work done in Great Britain or in one or other of the Colonies and U. S. A., the workmen employed being British, Canadian, Australian, American, Swedes, Norwegians, Italians and Spaniards.

As the length of shift worked by men varies in different countries, it is most convenient to employ the hour as the unit of time, and this measure will be used throughout the following costs, but the hour rate allows for meals:—

MINING.

Drifting or Tunnelling. Size of drift or tunnel 6¼ feet x 5½ feet (inside wood if timbered). Hand drills employed.

	Shale		Amphibolite		Millstone Grit.	Limestone.		Dolomite.	Volcanic Ash.
	1	1a	2	2a	3	4	4a	5	6
Miners' hours per foot driven	23	22	30	60	30	28	32	24	29
Dynamite, lbs. " "	.1	1.3	3.1	3.7	1.57	.1	3.	4.	1.5
Fuse, feet " "	2.	10.	17.	21.	10.	16.	10.	19.	18.
Caps, No. " "	.66	3.	5.	7.	3.	5.	3.	5.	6.
Candles or oil, lbs. " "	1.2	.9	1.26	2.1	1.	1.3	1.3	1.3	1.5
Points sharpen'd, No. per ft. driven	.28	3.6	12.	23.	19.	10.	6.	10.	6.
Advance in feet per hour (of day)	.11	.12	.82	.44	.7	.8	.7	.63	.7

1 and 1a timbered with sets 3 feet apart centres, the time includes that work. The dynamite used in 2, 2a and 5 contained only 50 per cent. of nitroglycerine. All the others 83 per cent. In 1, 3 and 4 single hand drilling was employed. In the others double handed.

	Granite.		Argillite.	Argillite & Quartz.		Quartz Vein.
	7	7a	8	9	9a	10
Miners' hours per foot driven	18	36	30	17	15	27
Dynamite, lbs. " "	2.77	3.47	.3	1.65	2.5	3.75
Fuse, feet " "	20	26.	13.	11.	12.	17.
Caps, No. " "	6.	6.5	3.5	3.	3.5	5.
Candles or oil, lbs. " "	1.2	1.4	1.2	.7	.5	1.38
Points sharpened, No. per feet driven	18.	72.	10.	5.	6.	13.3
Advance in feet per hour (of day)	1.5	.58	.89	1.6	2.1	.8

The dynamite used in 7, 7a, 8, 9 and 10 contained only 40 per cent. of nitroglycerine. In each case the drilling was double handed; 1 was driven along a fault; 1a was in hard solid granite; 8 was driven towards dip of bed; 9 and 9a alongside a fault.

In each of the above cases—1 to 10—time is allowed for tramming the broken rock a distance not exceeding 300 feet.

Air drills employed.

	Amphibolite 8 ft. x 8 ft. 2 drills.	Lava 7 ft. x 6½ ft. 2 drills.	Granite 6½ ft. x 5 ft. 1 drill.
Miners' hours per foot driven	20.	12.	12.
Dynamite, lbs. " "	12.	6.	3.6
Fuse, feet " "	31.	16.	15.
Caps, No. " "	6.	4.	4.
Candles or Oil, lbs. " "	1.89	1.4	1.3
Points sharpened, No. per foot driven	50.	40.	30.
Advance in feet per hour (of day)	.39	.45	.25

The labour cost includes tramming. The amphibolite tunnel was over a mile in length, and the above figures are the average of the whole length. Two-thirds of the dynamite used in that tunnel contained 60 per cent. of nitroglycerine, the remainder only 40 per cent. The dynamite used in the other two drifts contained 40 per cent. of n.g.

None of the rocks in the 13 instances given was decomposed except 7, 9 and 9a, which were driven along faults.

Shaft Sinking. Shaft 15 ft. x 5½ ft. inside of 4-inch wood, where timbered.

	Limestone.	Shale.	Boulder Clay.	Sandstone.
	1	2	3	4
Sinkers' hours per foot sunk	84.	30.	33.	37.
Bankers' " " "	18.	7.	7.5	8.5
Dynamite, lbs. " "	5.	3.5	.62	4.
Fuse, feet " "	33.	31.	6.	29.
Caps, No. " "	17.	10.	2.	9.
Candles or oil, lbs. " "	3.7	1.27	3.	1.7
Points sharpened " "	6.3	10.	2.2	11.

Nos. 2, 3, and 4 were close timbered with 4" deals and the figures given allow for this work. The time required to put in the framing and 2 midwalls or partitions is 6.8 hours per foot of shaft, including banker or pit-

top hand. 3.73 lbs. of 5″ and 6″ nails are required per foot of shaft timbered, and 2.4 lbs. of coach screws of various sizes for putting in slides.

Ore getting by drift and stope. A few instances of these operations will now be given:—

	Drifting 8 in. x 12 in.	Stoping 8 ft. wide.	Drifting 11 ft. x 11 ft.	Stoping 11 ft. wide.	Drifting 7 ft. x 5½ ft.	Stoping 50 ft. wide.
Miners' hours per 2240 lbs.	8.4	4.2	7.	3.9	6.4	1.4
Dynamite, lbs. " "	.28	.097	.3	.13	1.6	.25
Fuse, feet " "	2.2	.51	1.79	.73	10.	2.1
Caps, No. " "	.7	.16	.5	.2	.3	.6
Candles or oil, lbs. per 2240 lbs.	.24	.14	.36	.18	1.3	.2
Points sharpened " "	1.5	.21	1.3	.26	1.4	1.3

1 was hard, compact hematite; 2 hematite, hard and cellular; 3 copper ore consisting of quartz, pyrite, pyrrhotite and chalcopyrite with a little argillite.

Nos. 1 and 2 were worked by single handed drills; No. 3 by air drills. In Nos. 1 and 2 stope labour equals drift labour x .5 and .56 respectively, the stope being as wide as the drift. In No. 3, where the stope was nine times as wide as the drift, stope labour=drift labour x .22.

Side shooting of limestone can be done at the following cost:—Labour, 3.6 hours per ton. Dynamite, .22 lb.; fuse, 2 feet, and caps, 7 per ton. As compared with drifting 6′ x 5½′, the labour cost in side shooting (stoping) is drift cost x .35.

Rock drilling by hand drill, in limestone.

Single-handed, 75 blows per minute—

With 1⅛″ starting bit, bored 2′.6″ in 1 hr. 40 min. or 18″ per hour.

With 1 ″ starting bit, bored 2′.6″ in 1 hr. 30 min. or 20″ per hour.

Double-handed, 58 blows per minute—

With 1⅛″ starting bit, bored 2′.6″ in 1 hr. 9 min. or 26″ per hour.

These figures, as well as results on a larger scale, show that single handed drilling is more economical than double handed. It is, however, only in some countries that men are found who can handle single handed hammers efficiently.

Tramming, Trucking or Trailing.—When this work is done to a shaft, there is a loss of time at both ends of the run; at the working face in filling, at the shaft in waiting for the cage.

When filling out of hoppers or chutes a man can run in trucks holding 1,000 lbs., 3,500 lbs. per hour a distance of 500 feet. With larger trucks and a good road he can run more.

Winding Ore up Incline 67 feet long with a gradient of 1 in 2¼. Windlass geared 5 to 1, 2 men at handles. Cost in labour .42 hour per 2,240 lbs

Surface Work.

Quarrying.—Limestone dipping 1 in 5 and worked towards dip of beds.

Labour,	hours per 2,240 lbs.	1.1
Black powder,	lbs per 2,240 lbs.	.51
Dynamite,	lbs. per 2,240 lbs.	.022
Fuse,	feet per 2,240 lbs.	.26
Caps,	No. per 2,240 lbs.	.15
Points sharpened,	per 2,240 lbs.	.13
Total		1.172

The labour cost may be subdivided as follows:—Boring and blasting, .41; breaking and filling into wagons, .5; sundry work, .19 hour per 2,240 lbs.

Filling from bank, by spade and truck. Average run 38 feet, .28 hour per 2,240 lbs.

Tramway Building—

Earthwork, by pick and spade (sand, gravel and clay), lead 250 yards	per cubic yard	1.4
Ballasting, 10″ of limestone from pit dump for bottom, 6″ ashes for top	per cubic yard	1.4
Plate laying, 75 lbs. rails, 40 lbs. chairs.	per lineal yard, both rails	1.3
Fencing, posts 6 feet apart and 6 wires	per lineal yard,	.5

Making Puddle Wall. Clay led 120 yards. Average width of puddle trench, 12 feet.

		Hour
Getting clay and filling into carts	per cubic yard	.68
Leading and dumping (horse, cart and man)	per cubic yard	1.88
Throwing clay into puddle trench	per cubic yard	.89
Levelling in puddle trench	per cubic yard	.45
Cutting twice in puddle trench	per cubic yard	.52
Pumping water	per cubic yard	.22
Total	per cubic yard	4.64

Timbering puddle trench takes .53 hours per square yard of timbering. To take it out required .13 hour per super yard.

Making Concrete.—1 of Portland cement, 2 of sand, and 5 of broken stone (1½ ring).

		Hour.
Gauging, sand wheeled 10 yards, cement 40 yards, stone at hand	per cubic yard	1.2
Mixing	per cubic yard	2.0
Wheeling and dumping	per cubic yard	.96
Water boy	per cubic yard	.29
Total	per cubic yard	4.45

The following quantities of materials were used per cubic yard of concrete:—

Cement	lbs.	226
Sand	cubic feet	10.1
Stone	cubic feet	25.0

When the mixed materials were put into the stone gauge they rather more than filled it, showing that the interstices between the stones were more than filled.

Erecting shoring for concrete walls. .67 hours per super yard of shoring.

Laying earthenware socket pipes. 3 feet long exclusive of socket.

Diameter of pipe—		9″	12″	15″
*Excavating trench,	hour per lineal yard	1.26	5.7	1.28
Laying pipes,	hour per lineal yard	.37	.56	.45
Filling in trench,	hour per lineal yard	.72	1.4	.81
Carting soil off ground,	hour per lineal yard	.1	.1	.016
Horse,	hour per lineal yard	.014	.018	.015
Yarn, lb.	per lineal yard	.09	.125	.022
Cement, lbs.	per lineal yard	2.5	3.3	4.2
Average depth		4′.6″	8′.3″	4′.0″

The cement joints were made of mortar 1 to 1.

Laying cast iron socket pipes, 2″ pipes 6 feet long, the others 9 feet, exclusive of sockets.

Diameter of pipe—		2″	3″	4″	7″	9″
*Excavating trench,	hour per lin. yd.	.26	.46	.5	.8	.85
Jointing,	hour per lin. yd.	.09	.08	.1	.28	.3
Filling in and rem'v'g surplus,	per lin. yd.	.23	.23	.25	.38	.42
Yarn, lb.	per lin. yd.	.14	.2	.25	.5	.6
Lead, lb.	per lin. yd.	.42	.83	1.0	1.66	2.2
Depth of trench		2′.3″	2′.3″	2′.7″	3′.0″	3′.6″

Masonry, stone dressing, sandstone.

Edging, 3″ Flags. Mason 1.6 hour per super yard.

Rock-faced coping, 16″x8″ with arris drafts on front angles. Bed broached. Back unworked. Mason, .45 hour per lineal foot.

Tooled steps, 18″x18″, Bed broached. Mason, 2.79 hours per lineal ft.

Tooled steps, 15″x9″, Bed broached. Mason, 1.5 hours per lineal ft.

Blocking, 8 to 18″, average thickness 9″. Mason, 1.76 hours per lin. ft.

Stone setting.

Engine pillars, 5 feet wide at base and 4 feet wide at top. Height, 6 feet. Built of rubble set in slag mortar. Large stones used.

	hours.	
Cost for Masons	4.7	per cubic yard
Cost for Labourers	2.25	per cubic yard

476 lbs. of slag mortar, made of slag lime and ashes, ground together, was used per cubic yard.

Breast Wall. Face of Blocking 9″ thick, rubble backing. Average thickness 3 feet, facing stone ready dressed. Mason, 5 hours; Labourer, 4.6 hours per cubic yard

Breast wall similar to last, but only 1′.9″ thick. Mason 6, and labourer 5 hours per cubic yard.

Breast wall of rubble, 4′.6″ high, 2′.3″ thick. Mason 1.9, and labourer .94 hours per cubic yard.

Wall 4 feet thick, of granite rubble. Mason 1.6, and Labourer 2.3 hours per cubic yard.

Wall, 2′.10″ thick (facing stones cut ready). Mason 3.9 and labourer 1.9 hours per cubic yard.

Dry rubble fence wall, 5 feet high x 18″ thick. Mason 3.6 hours per cubic yard. No labourer required, as the stones were laid along one side of the wall.

Setting Ashlar steps, 15″ x 9″. Mason .22 and labourer .22 hour per cubic foot.

Setting Ashlar coping, 15″ x 9″. Mason .25 and labourer .25 hour per cubic foot.

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*Sand, gravel and clay.

Setting Ashlar Coping, 29 x 18″. Mason, .29 and labourer .075 hour per cubic foot.

9″ pitching with squared stone. Mason .19 and labourer .13 hour per super yard.

Mortar used in pitching (1 cement to 4 sand), 448 lbs. cement and 18 cubic feet of sand per super yard of pitching.

Laying 3 flags. Mason, .99 and labourer 1.17 hour per super yard.

Pointing, Ashlar work. Horizontal joints 12″, vertical joints 24″ apart. Mason .07 and labourer .07 hour per super yard on plain wall, exclusive of time required to fix blocks, etc.

Pointing, Blocking, .4 hour per super yard, within 5 feet from ground.

Brickwork.

Wall 2 feet thick, bricks set in neat cement and joints thoroughly filled. Bricklayer 5.5 and labourer 7.9 hours per cubic yard.

1½ Brick wall (interior). Bricklayer .7 and labourer .7 hour per super yard.

2½ Brick wall (exterior). Bricklayer 1.8 and labourer .7 hour per super yard.

Brick piers, 2′.10½″ x 1′.7½″ x 5′.6″ high. Bricklayer 4.6 and labourer 4.7 hours per cubic yard.

Semi-circular arches, 7′.6″ span, 1′.7½″ wide and 1 brick thick. Bricklayer, 5.1, and labourer 5.1 hours per cubic yard.

Segmental arches, 15′.0″ span, 43½ feet long x 14″ thick. Bricklayer 2.4 hours and labourer 2.2 hours per cubic yard, exclusive of erecting and taking down centering. Cement used (1 to 1), 240 lbs. per cubic yard. To erect centering took 1.3 hour per cubic yard of arching. To take it down .83 hour per cubic yard.

2 feet barrel culvert 9″ thick. Bricklayer 1.2 and labourer 1.5 hour per cubic foot.

3½ feet barrel culvert, 14″ thick. Bricklayer 3.3 and labourer 4.1 hours per cubic foot.

Chimney, 60 feet high, 7′ x 7′ at base and 4′.7″ x 4′.7″ outside at top.

	Thickness	Hours per cubic yard. Bricklayer.	Labourer.
Up to 16 feet	18″	3.4	5.0
Up to 32 feet	14″	3.4	5.7
Up to 40 feet	14″	3.6	6.3
Up to 47 feet	9″	4.2	7.6
Up to 57½ feet	9″	4.5	8.1 including cornice

Carpenter Work—

Making gallows—or pit head—frame, containing 578 cubic feet.
Planing timber, .24 hour per cubic foot.
Mortising, tenoning, chamfering and framing, .64 hour per cu. ft.
Erecting, 1.52 hour per cubic foot.

1,508 lbs. of bolts and straps. To place in position two 10-foot pulleys took 72 hours.

Putting on cleats for fixing slides (cleats 5 feet apart) 4 nails to each, .042 hour per foot of compartment, exclusive of banker or pit headman.

Putting in slides, .063 hours per foot of compartment, exclusive of crabmen and banker.

Putting in slides, .22 hour per foot of compartment, all hands.

Preparing slides, 4′x3½′ (planing and scarfing), .22 hour per lineal foot.

Engine house, 31'.6" x 25'.6" inside x 7'.6" to eaves. 1,985 super. feet in roof and sides, including 4 windows 3'.6" x 2'.9" and one 7'.6" x 3'.0".

Planing and chamfering timbers, for frame. Carpenter .07 hour per square foot of walls and roof.

Framing. Carpenter .2 hour per square foot of walls and roof.

Erecting frame. Carpenter, .06 hour per square foot of walls and roof. and .027 hour for labourer.

Planing 1" boarding for sides and roof, .063 hour per square foot, one side only of roof boards planed.

Fixing 1" boarding for sides and roof, .058 hour per square foot, and .022 hour for labourer.

Flooring fitted to drum space and bed plate of coupled engines. Carpenter .034 hour per super foot of total area of engine house.

Putting on ordinary boarding or siding (10" boards). Carpenter .16 hour per super. yard.

Putting on drop siding. Carpenter .18 hour per super. yard.

Putting on corrugated iron siding. Carpenter .25 hour per super. yard.

Studding, 6" x 2", 16 feet high with girts every 4 feet. Carpenter, .25 hour per super. yard.

Shingle boards (on roof). Carpenter, .19 hour per super. yard.

Hewing timber. Spur of gallows frame 61 ft. long x 14 square at one end, and 9" x 9" at the other. Hewn from a tree 2 feet diam. at butt end. .07 hour per super. foot.

Shaft framing, 12" x 6", hewn from timber 15½ diam. .037 hour per super. foot. Back, only roughly hewn.

Pump rods sawn to 8" x 8". Making joints and putting 4 iron plates on to one end ready for uniting to adjoining piece in shaft. 8 hours per joint.

Putting felt on to roof. .16 hour per super. yard.

Sundry Data—

Pumping water by hand. Pump barrel 5" diam. x 7" stroke. Average height water was lifted 15 feet, .007 hour per gallon.

Unloading ore from ship by steam crane and swivel bucket. Ore fine, good filling, seldom needed touching with a pick, 350 tons per 9 hours.
Men in hold and at hatchway, .18 hour per ton.
At steam crane and in wagon, .051 hour per ton.

Loading coal by lowering loader, 165 tons per hour from wagons carrying 9,240 lbs.
Horses and drivers, .02 hour per ton.
Men on loader, .029 hour per ton.
Trimmers in ship, .05 hour per ton.
Total, .099 hour per ton.

Carting Earth. Distance, 160 yards. Fairly good road across fields.
Filling, .24 hour per cubic yard.
Leading and returning, .15 hour per cubic yard.
Tipping, .06 hour per cubic yard.
Total, .45 hour per cubic yard.

Barrowing Earth, 66 yards (barrow holds 2¼ cubic feet), .06 hour per cubic yard.

The above figures cover only a small part of any engineer's operations, but they are sufficient to illustrate the prin-

ciple advocated herein. Suppose it were required to estimate the money cost of the labour of driving a 6′ x 5½′ drift in limestone in the Province of British Columbia. All that is necessary is to take the labour cost from the table above relating to that description of work and multiply it by 43c.—the wage per hour in that province—and the money cost per foot of drift is obtained. If we take 30 hours as the labour cost of driving a 6′ x 5½′ tunnel in limestone, then 30 x 43c.=$12.90, the money cost per foot of labour. If the drift were to be driven in Algeria, where a miner gets about 7c. per hour, the money cost per foot—other things being equal—would be $2.10. But there about 20 per cent. has to be added on account of defective methods.

The money value of the materials needed, such as explosives and illuminants, is obtained in the same way.

The above figures are for straightforward work; interruptions must be allowed for.

OPERATING COSTS AT A SMALL FREE-MILLING GOLD MINE.

By A. H. Gracey, Nelson, B.C.

The following cost data, relating to the mining, milling, etc., of a small vein of free milling gold ore, are presented in the hope that they may be of practical interest.

The operations under review were carried on about seven years ago and better results could have been attained had sufficient capital been provided for preliminary underground development purposes. This deficiency, however, has not been an unusual condition in the beginning of various mining operations in this country. With development kept well in advance of ore extraction a much larger average output could have been maintained and the costs here given could possibly have been reduced from 20 to 25 per cent.

The property in question is situated on a mountain at an elevation of 6,000 feet above sea level and 4,300 feet above the nearest railroad supply point, with which it is connected by seven miles of switchback wagon-road. The mill is situated on the same road two miles nearer town.

Snow lies on the property for seven months of the year and falls to a maximum depth of from 6 to 8 feet.

The ore in the vein consisted of a more or less shattered and banded quartz. The sulphides were almost entirely converted into oxides and the vein and adjoining ground has become soft and friable. The vein crossed at right angles a contact between altered dark green grained schists of igneous origin and granite. Most of the ore mined came from the schist area.

The dip of the vein averaged 38° from the horizontal and in many places was less. This characteristic is important when considering the mining cost, as at very few points in the stopes would the ore run by gravity to the chutes below.

The walls of the vein were usually well defined, but the filling was variable. It was seldom entirely filled with quartz, but usually with one or more bands of quartz, from 4 to 18 inches wide (constituting the "pay streaks") enclosing wider bands of decomposed, soft, barren country rock. The average width of the quartz ore was about 18 inches. Under these conditions a considerable quantity of waste was unavoidably intermixed with the ore. About 30 per cent. of the ore as delivered at the mill was originally fine waste, which, of course, became more or less enriched with the fine oxides.

In a large area of the stoped ground the hanging wall was loose and blocky, necessitating close stulling with head boards or caps. Numerous small slips and faults occurred, especially near the surface, and these together with pinches, or barren areas, several hundred square feet in extent, interfered with the regularity of the stopes. During spring and early summer the workings were very wet, adding thereby to the difficulty of handling the soft ore.

Ample timber for all purposes was available on the property and the only cost connected therewith was that of labour.

The mine was opened by adit levels all driven on the vein, and averaging about 100 feet apart on the dip. As the dip of the vein was nearly coincident with the surface of the hill comparatively shallow depth was attained, even at the end of the lowest tunnel, which was about 750 feet in length.

The maximum area of the vein from which ore was mined measured approximately 600 feet on the strike and 480 feet on the dip.

All ore from throughout the mine was delivered through chutes to the lowest level and in order to secure sufficient grade in these chutes so that the ore would run by gravity, it was necessary to cut back into the foot wall in the lower level and the hanging wall in the upper level. In consequence the ore had to be transferred at each level.

All mining was done by hand, which, I believe to be the most economical method in a deposit of this character when worked in a relatively small way.

From the lower level the ore was trammed in cars (18 cu. ft. capacity) to the ore bin at the terminal of an aerial wire rope tramway, double rope system. This tram was 7,300 feet in length and delivered the ore into bins above the mill from which it was trammed in a car (16 cu. ft.) to the crusher grizzly, each car being weighed en route.

The mill, which for some years had been operated in connection with an adjoining property, contained ten stamps weighing newly shod 950 lbs., and four Frue vanners. It was driven by water power except for two or three months in the winter, when steam was used on account of low water. The flume was old and gave considerable trouble. When using steam power the milling costs were more than doubled.

The cyanide plant consisted of two settling tanks with automatic distributors, five leaching vats, and the necessary solution and sump tanks. The treatment was by simple percolation, and the capacity of the plant was about 50 tons per day. To secure satisfactory percolation it was necessary to separate the slimes as thoroughly as possible and for this purpose a spitzkasten was installed in the mill below the amalgamation plates. The sands were sent direct to the settling tanks and the slimes, after passing over the vanners, went to waste. The resulting concentrate from the vanners were shipped to the smelter. The slimes amounted to about 30% of the plate tail.

Wages paid were as follows:

Miners, 8-hour shift	$3.25
Muckers, 8-hour shift	3.00
Timbermen, 8-hour shift	4.00
Blacksmiths, 9-hour shift	4.00
Average mill and cyanide (12 hours)	3.80

During the operating period the average daily output of the mine was 22 tons, whereas it would have been possible to mill an average of 30 tons in the same period. The conditions in the mine (chiefly lack of advanced development), made it impossible to maintain regularly an output equal to the maximum capacity of the mill. This meant that during certain periods the mill was worked with short shifts or inoperative.

Cost of handling 13,958 tons:—

Mining—Stoping	$3.46		
Mucking	0.64		
Timbering	0.43		
Total labour		$4.53	
Supplies		0.51	$5.04
Milling			0.925
Cyaniding			0.725
Aerial tramming			0.16
Marketing product (concts and bullion)			0.135
Management, general expenses, insurance, taxes			0.675
Maintenance of plant			0.26
Total			$7.92

The mining cost does not include the development cost of driving the main levels and connecting raises, which amounted to $1.90 per ton of ore extracted, but does include cost of intermediate prospecting, such as drifts and raises; and much of such work was necessary. Nor are there included interest on capital or depreciation charges. The maintenance of plant cost, includes all repairs and additions necessary to keep the plant in an efficient condition.

COSTS AND COST-CONDITIONS AT BLUEBELL MINE, BRITISH COLUMBIA.

By S. S. Fowler, Nelson, B.C.

(*Trail Meeting of Western Branch*, 1911.)

If I may be permitted to judge from my own experience of some twenty-five years duration, many of the members of this Institute must, on more than one occasion, have been forced to realize that their original forecasts of the probable results of the operation of new mining undertakings were little if any better than poor guesses. Few of us have had or can have so extended an experience as to make us entirely self-dependent and, therefore, we turn naturally to the chronicles of the experiences of others for assistance. But if in search of cost-data we examine the pages of our "Journal" and those of other similar institutions, I, for one, am impressed with what seems a lamentable absence of such figures as will apply to the conditions, physical or otherwise, with which I am often confronted.

There are, doubtless, in many instances, temporary and cogent reasons for not divulging cost-data; but in the great majority of cases, there is no real necessity for secrecy and the publication of such information would undoubtedly be of the greatest possible value and utility to mine operators and engineers. Therefore, I plead for the wider and more detailed recording of the cost of ore-mining and ore-treatment, accompanied necessarily, by a statement of the conditions under which such cost is obtained. In the hope, then, that an example in this direction may be emulated by members of the Institute in general, I present herein a statement of costs and conditions concerning the mining and concentration of ore, on a fairly large scale, at the Bluebell mine.

General Conditions.—The Bluebell mine is situated on a peninsula which projects from the east side of Kootenay Lake,

British Columbia. The ore-bodies, outcropping at one-hundred feet or less above the water-level, are attacked through an adit whose portal is within one-hundred yards of a wharf at which all supplies are received and from which all product is shipped. Adjacent to the portal, are the concentration plant and shops; and the office, laboratory and living quarters (save certain cottages) are within two hundred yards thereof, whilst the greatest distance from which the ore so far developed requires to be hauled does not exceed three hundred yards. It will be observed, therefore, that accessibility is practically perfect. Nelson, the chief source of ordinary supplies, is distant about thirty-two miles by boat.

The living quarters comprise (a) several four-room cottages all plastered and painted, situated about five hundred yards from the work, provided with water and electric light and each surrounded by a fenced plot of ground 60x120 feet. These cottages are rented to employees with families at $12.00 per month each. (b) A bunk-house containing twenty-seven bedrooms and two recreation rooms. All of these are plastered and painted and open on to covered verandahs, there being no internal passages. No more than three men may occupy any one bed-room. (c) A "dry"-house adjoins the bunk-house and contains in one room, six shower baths with cement floors and ample sinks, laundry tubs and hot and cold water. In a connecting room are lockers properly ventilated and provided with steam pipe below. Toilets are in a small, separate but conveniently placed building and are fitted with flush closets on a cement floor. All buildings are steam-heated when necessary. (d) Within fifty yards of the bunk-house is the boarding-house with seating capacity for one hundred. In the basement of this building is a post-office (Riondel) and a store supplied with the commoner necessities of the employees; but no employee is either compelled or influenced in any way to trade here. The dining-room is ceiled, painted white and amply lighted on north and south sides, thus being a cheerful place whose influence on the dispositions of those who use it—to say nothing of their appetites—is notably favourable.

An easily accessible field situated some three hundred yards from the living quarters is much used for sports and several of

the men have maintained their own canoes and small motor-boats in the near-by bays.

Without reference to the natural, and quite exceptional beauties of the surroundings, such are the conditions which affect the lives and work of those who labour at Bluebell. It need hardly be said that they attract the best class of men, who, when once they have secured employment, usually are not desirous of change.

On the part of the management there has been no attempt at paternalism. The sole prohibitions are canvassing, gambling and over much drink. It does nothing and provides nothing which may be regarded as charity. The result has been that whilst doubtless all hands realize that low costs are essential to a continuance of operation the men as a staff also possess what may be termed a "collective conscience," the existence of which has contributed in large degree, no doubt, to low costs in a country of high wages and expensive materials.

Wages.—Practically all work has been done by day-labour rather than by contract and the wages paid (regarded as "standard" for the district) are as follow:—

Foremen	$5.00 to	$6.00	for 8 hours
Shift-bosses	4.00 "	4.50 "	"
Machine miners and helpers		3.50 "	"
Hand miners		3.25 "	"
Mill hands	3.00 "	4.00 "	"
Smiths and helpers	3.50 "	4.00 "	9 "
Compressor-runners		4.00 "	8 "
Muckers		3.00 "	"
Carpenters & machinists	.50 per hour.		
Outside labourers		3.00 "	9 "

The approximate average wages for all classes =$0.433 per hour.

Ore-Extraction.—All charge for development, previous to the period under review, has been either written off or placed to capital account. The following statement, therefore, includes no provision for work under that head. As already stated, the ore is attacked through an adit and all stoping has been done

from above that level, consequently no charge for hoisting, pumping or other expense incidental to working from shafts appears.

The ore-bodies are found in the upper part of a bed of limestone over one hundred feet in thickness, striking north and dipping west at about 35°. The deposits, of which only two have been worked, whilst they have a well-defined and strong roof, are irregular in plan and section and may be classed as large in size, the workings as a whole taking the form of chambers as much as one hundred feet wide in a north-south direction, and, say, from ten to fifty feet or more in height. This statement implies large ore-faces. Wherever necessary or advisable, pillars of ore have been left from time to time for the support of roof; but subsequently some of these were removed without difficulty or danger. In this manner, timbering for support has thus far been successfully avoided and, practically the only timber in the mine is in chute-timbers and track-ties. Whilst several rises through limestone underlying ore have been made to serve as ore-passes, the irregularity of parts of the deposits has necessitated much shovelling and wheeling, thus off-setting to a considerable extent the main advantages of large working-faces and little timbering.

As a rule the ore may be said to drill and break well, although much of the lower grade of material contains a large proportion of quartz which causes unusual wear of drill-steel.

Power is derived from water under a static head of over 700 feet and is applied to compression of air for the operation of 3¼ in. piston drills and one hammer drill. Generally, one of the former has been in use for three shifts per day, and one for two shifts, while the hammer-drill was employed on one shift only. These three machines with three or four hand-miners engaged in narrow work, maintain the output of the mine to the requirements of the mill, about 160 tons per day.

The ore is hauled in trains of five 16-foot cars drawn by a horse, except when, at night, a few occasional cars are taken out by hand. The cars are commonly loaded by muckers also, who assist the driver in making up trains at the several loading chutes.

The normal underground crew consists of:

Foreman and Shiftboss	2
Timberman	1
Driver	1
Miners	14
Muckers, etc.	15
Total	33

The cost of ore-extraction under the above conditions follows:

BLUEBELL MINE, B.C.

Cost of ore-extraction from 1 July, 1909, to 31 March, 1910.

Tons mined	43,069
Feet deadwork	200

	Labour per ton $	Supplies per ton $	Total per ton $
Direct Labour:			
Foremen and Bosses	.055	.....	
Timberman and Nipper	.042	.....	
Miners	.299	.....	
Muckers and Loaders	.235	.....	
Driver	.019	.....	.650
Direct Supplies:			
Dynamite 40% at 14. 9c. lb.		.147	
Fuse " $24.00 case			
Caps " $6.50 M	.....		
*Candles " $5.33 c/s	.....	.013	
†Drill pts. and steel	.....	.014	
Miscellaneous	.....	.019	.193
‡Power and Light (proportion)	.067	.011	.078
Shopwork, repairs etc., (proportion)	.055	.008	.063
Totals	.772	.212	.984
Per cent	78.5	21.5	100

Approximate segregation of the above:

Breaking	$ per ton	.647	%66
Mucking, etc.	"	.272	" 28
Haulage	"	.033	" 3
Timbering	"	.032	" 3
Concentration:		0.984	100

*Some of the ore was won from "glory-holes"—daylight.

†First cost of machines, rails and cars had been written off.

‡This includes only compressormen's wages and all repairs—not interest or amortisation.

In round figures the ore consists of:

Quartz and limestone	35%
Pyrrhotite	35%
Marmatite	20%
Galena	10%

The mixture of these minerals is fairly coarsely crystalline and quite easily separable. The object of concentration is the recovery of galena, of which probably 85% is found in sizes between 2mm. and 10mm., and the greater part of that quantity is associated with the pyrrhotite rather than with the other materials. Occasionally galena is found sufficiently compact and clean to permit of recovery by hand-sorting; but usually it is too fragile to render sorting commercially feasible. Silver is present in the galena to the extent of about one-fifth of an ounce to the per cent. of lead, the clean iron and zinc minerals carrying each about one ounce per ton.

The ore is dumped, after weighing, to a coarse breaker set in a pit below the adit-level track and thence is elevated by belt-conveyor to the top of the mill. After passing through another breaker and rolls it goes through the common treatment by Hartz jigs and Wilfley tables.

The concentrate, after storage in bins at the level of the adit, is shipped from time to time in bulk on barges from which it is transferred either at Proctor or Nelson at railway company's expense and thence sent to the smeltery at Trail.

The essential differences between this ore and the scheme of its concentration and those of most other British Columbian mills, are found in the necessity, at present, of elevating all of the ore before treatment, and the presence of the large amount of lead-bearing pyrrhotite middling requiring re-crushing—one-third only of the ore being gangue in the ordinary sense.

The plant is operated in three shifts by a boss, a jigman, and a tableman on each, whilst on the day-shift only, three other men are engaged in dumping, weighing, crushing and miscellaneous work, making a total of twelve.

The major repairs are conducted on shipping days when ordinary running is suspended. A carpenter and a machinist assist

at repair work but are not regarded as part of the normal mill-crew. Water-power is applied through five 24 in. impulse wheels; but no part of the prime cost is included in the cost of operation. Heating is done from a central boiler-plant, when necessary.

Under the above conditions the following costs are obtained:

BLUEBELL MINE, B.C.

Cost of Concentration 1 July, 1909, to 31 March, 1910.

Tons treated	43,069	%
Hours running	5,494	83.6%
Hours lost, repairs, etc	994	15.1%
Hours lost, holidays	88	1. 3%

	Labour per ton $	Supplies per ton $	Total per ton $	Per cent.
Running :				
Bosses, jigmen, tablemen	.186	.....	.....	
Weigher, crusher, miscellaneous	.059	.....	.....	
*Heat, light, power	.008	.014	.....	
Total	.251	.014	.256	53.4
Repairs :				
Labour of crew and misc. labour	.085	.....	.....	
Sup. for breaking, rolling etc.	.....	.031	.....	
Sup. for conveying, elevating, pumping, launders, etc.	.....	.042	.....	
Sup. for sizing, jigging, tabling, etc.	.....	.026	.....	
Sup. for miscellaneous	.....	.036	.....	
Total	.085	.135	.220	44.4
Loading concent. on barges	.013	.....	.013	2.2
Total Concentration	0.349	0.149	0.498	
Per cent	70	30	.....	100

It is fair to remark that while the cost above given is not unduly high, it might have been considerably lower had circumstances permitted the employment of adequate working capital.

Shopwork, etc.—Besides the employees directly concerned with the mining and concentration operations, there are employed:

*Operating, labour and repairs only. Interest and amortisation not considered.

3 Compressor runners who also fire boiler for heat.
2 Blacksmiths and helper.
1 Carpenter.
1 Machinist.
1 Labourer.

The wages of these men, together with the cost of any material used by them, are allocated above the proper accounts.

General Expenses.—These include:

(a) Salaries of Manager, Superintendent, Accountant, Assayer, etc.

(b) Common office expenses, assay supplies, travelling, etc.

(c) Taxes, insurance, bank charges, legal expenses and any other property chargeable to operation; but do not include interest on investment nor amortisation and their sum is:

General expense .....$0.376 per ton.

Summary:—

Ore extraction.	.984	per ton
Concentration and shipping	.498	"
General	.376	"
Total.	1.858	

In conclusion let me say that I have purposely omitted any charges which pertain to interest and redemption of capital as quite apart from the object of this paper. Such figures, whilst they are all important in determining the outcome of any venture, are here presumed to be determined by others and, ultimately, such determination may be regarded as a function of directors rather than of an operating manager.

A NOTE ON MINING AND CONCENTRATING COSTS AT LE ROI NO. 2 MINES, ROSSLAND, B.C.

By Ernest Levy.

(*Western Branch Meeting, Trail, B.C., May,* 1911.)

The ore-bodies are very erratic, both as to position and variability in size, as well as disposition of values; additional difficulty is experienced owing to the visible characteristics of the ore seldom indicating its value at all, and this involves constant recourse to assaying. The ore-bodies vary in width from a knife edge to 30 feet, and so necessitate the use of both the square set and "shrinkage" stoping methods of ore extraction. The latter system is exercised to as great an extent as practicable on account of its smaller cost. By far the larger proportion of past production has been derived from between the 300 and 700-foot levels of the Josie mine.

The main shaft of the Josie mine inclines at 74 deg., has three compartments and extends to the 1,300-foot level. It is a three-compartment excavation 14 ft. 6 in. by 5 ft. inside the timbers, and is equipped with a 150-h.p. double conical drum hoist. The shaft building is furnished with grizzles, 4 in. and 1 in. spaces, on which hand-sorting takes place. The ore is divided into first-class, second-class and mill ore. The first-class fines are shipped to the smeltery, and the remainder sorted into shipping, mill and waste ore; the second-class fines are sent to the mill, and the remainder distributed as in the case of the first-class. The mill ore is trammed direct to the concentrator.

The No. 1 shaft is a three-compartment shaft, 800 feet deep, and equipped with a similar hoisting engine to that at the Josie shaft and sorting floors.

To give an idea of the extent of operations and what is accomplished by hand-sorting, the figures covering the last financial year may be exhibited. They are as follows:—

	Tons extracted.
First-class ore	42,770
Second-class ore	5,790
Mill ore	4,480
	53,040

which by sorting was resolved into:—

	Tons.
Shipping ore	29,776
Mill ore	17,553
Waste	5,711
	53,040

Stoping costs per ton were:—

Ore production:—Labour	$0.76
Explosives	0.32
Illuminants	0.03
Sundries	0.04
Ore-sorting labour	0.21
General expense	0.35
Power plant labour	0.07
Supplies	0.36
Mine general labour	0.33
Supplies	0.07
	$2.54

The ore shipped averaged in assay:—
Gold, 0.8882 oz.
Silver, 0.8086 oz.
Copper, 1.6305 per cent.

During the financial year under notice there was accomplished 4,202 feet of driving and cross-cutting and 160 feet of raising and winzing, which cost 17.72 per foot.

In addition to this the main shaft was sunk 193 feet at a cost of $75.56 per foot, and 11,508 feet of diamond-drilling was done at a cost of $1.73 per foot. The average depth of drilled hole was 371 feet.

Costs for five successive years are shown in the following table:—

Year ending	Drifting and Cross-cutting Feet	Raising and Winzing Feet	Total Footage	Cost per foot Total
1910	4202	160	4362	17.72
1909	3220	338	3558	14.35
1908	4302	270	4572	14.17
1907	2538	255	2793	14.58
1906	3392	187	3559	12.91

The concentrator is capable of milling and treating 60 tons per diem. The machinery is electrically driven by motors aggregating 100 h.p.; and it comprises one 9 by 16-in. and two 8 by 12 in. Blake crushers, two 6 ft. Chilean mills and four Wilfley tables.

During the last financial year the following grade of ore was treated, with the results as shown:—Feed: 17,265 tons, assaying gold 0.122 oz., silver 0.255 oz., copper 0.554 per cent. Concentrate produced totalled 1,368 tons, assaying gold 1.297 oz., silver 0.748 oz., copper 1.144 per cent. Cost per ton crushed was $0.99.

As a result, of the company's mining and milling operations in Rossland during the financial year October 1, 1909, to September 30, 1910, the net profit was $249,255.81.

THE COPPERMINE COUNTRY.

By J. B. Tyrrell, M.A., F.G.S., F.R.S.C.

(*Annual Meeting, Toronto, March, 1912.*)

The Coppermine country is situated about the centre of the northern coast of North America, just south of the Arctic Ocean, the shores of which are low, shallow and covered with ice for most of the summer.

Whaling ships now regularly navigate the Arctic Ocean from Behring Strait as far eastward as the mouth of the Mackenzie River, but from this point eastward navigation becomes more difficult and more impeded with ice, so that it has rarely been possible for such vessels to reach the mouth of the Coppermine River.

The country here considered is of unknown area, but speaking generally, it lies near the mouth of the Coppermine River and would appear to extend one hundred miles or more westward from it along the Arctic Coast and about two hundred miles eastward from it. Taking its centre as a point on the Coppermine River, about thirty miles above its mouth, this centre lies nine hundred miles northwest of Fort Churchill, on Hudson Bay, five hundred and fifty miles west-northwest from the head of Chesterfield Inlet on Hudson Bay, three hundred miles north of Fort Rae on the north arm of Great Slave Lake, and fifty miles east of Great Bear Lake.

At the present time the easiest method of reaching it is to descend the Mackenzie and Athabasca Rivers from Athabasca Landing to the mouth of Great Bear Lake River, to ascend this river to Great Bear Lake, cross Great Bear Lake, and thence to strike across the country eastward from Great Bear Lake to the Coppermine; but the main difficulty in this route is caused by the fact that Great Bear Lake, which is very large, having an area of 11,800 square miles, is only open throughout its whole

extent for about two months of each year, from the first of August to the first of October.

A canoe route leads north from Great Slave Lake (area 10,700 square miles) to the east end of Great Bear Lake, and thence to the Coppermine River. It is available for a little longer time than the other, in fact from the time when Great Slave Lake opens on the first of July until it freezes again on the first of November.

A party travelling through, or stopping in, that country can add largely to its supply of provisions by catching the fish which are so abundant in the rivers and lakes, and by shooting the caribou which roam in vast herds over the open plains; but it is never safe to depend on these sources of supply, for both may fail at critical times, or if they do not entirely fail they may become so scanty as to tax the strength and energy of the party in order to obtain sufficient food to support existence, while that very strength and energy should be devoted to prospecting and exploration. It would, therefore, be advisable for any party entering the country to take with it provisions sufficient to supply at least two-thirds of the normal rations, chiefly in the form of cereals, sugar and fat, while the region itself might be depended on to supply a fair quantity of lean meat.

The Coppermine River itself, which flows through the middle of the Coppermine country, is a stream from four to five hundred miles long. It rises somewhere to the east or northeast of Point Lake (Indian—"*Ekka tua*"), and flows from that lake northward to north latitude 67° 48′, where it empties into Coronation Gulf, one of the great bays of the Arctic Ocean, five hundred miles east of the mouth of the Mackenzie River. The stream is swift, but rather shallow, and is broken by numerous rapids, though most of these can be descended in canoes under the guidance of good canoemen. The ice on it breaks up annually about the first of June and does not form again until about the first of October. Its Indian name is *Tzan dézé*, meaning Metal River.

The Coppermine country lies within what are known as the Barren Grounds, or, to use the proper translation of the Indian

name, the Treeless Region, where all the uplands are devoid of trees and almost devoid of shrubs, and bear but a stunted growth of grasses, sedges, and low Arctic annuals. Near the head of the river some trees, chiefly spruce, tamarac and poplar, grow around the shores of Point Lake, and groves of smaller trees extend northward along its banks to within twenty miles of its mouth.

For more than two hundred years native copper has been known to exist on the banks of the Coppermine River, and over large areas in its vicinity. Writing about 1714, M. Jeremie, who had been in charge of York Factory or Fort Bourbon, then the most northerly trading post on the west side of Hudson Bay, between 1708 and 1714, while it was in the hands of the French, says of the Dogribbed Indians: "They have in their country a mine of red copper so abundant and so pure that without putting it through the forge, just as they obtain it at the mine, they pound it between two stones and make anything that they wish with it. I have often seen it, since our Indians constantly bring it from there when they go in war parties."

Thus the French traders, who travelled so far through the northern country and have told us so much about it, were the first to give us information about this region which still seems so remote and difficult of access.*

After York Factory and the other trading posts on Hudson Bay were handed back by the French to the English and to the Hudson's Bay Company, those in control of this latter company immediately began to look for the great mine of copper from which the Esquimaux and Indians derived their supply of the metal, and as early as July, 1717, they sent out Richard Norton, a boy about seventeen years of age, who had shown a great aptitude for learning the Chippewyan Indian language, with two of these Indians. No account of Norton's journey has ever been published, but from the remarks of Captain Middleton and

*In 1631,, Luke Fox, when travelling along the west shore of Hudson Bay about north latitude 63°, opened some Esquimo graves and found "darts" with iron and *copper* heads, the latter having doubtless been obtained from the deposits of native copper on the north coast of America: *The Voyages of Captain Luke Fox and Captain Thomas James*, Hakluyt Society, London, 1894, p. 320.

Arthur Dobbs, it would appear that he spent about a year travelling with the Indians, and there is a possibility that he went as far north as the Coppermine River itself. At all events, judging from the reports brought back by him and from the reports of the Northern Indians, Captain Christopher Middleton, F.R.S., writing in 1743, makes the following remarks:—

"All the Indians I have ever conversed with, who were at the Copper-mine, agree in this; That they were two Summers going thither, pointing towards the north-west and Sun-setting, when at Churchill; and that where this Mine is, the Sun, at a certain Season of the Year, keeps running round the Horizon several times together, without setting. Now we know from the Principles of Cosmography, that this cannot be true of any place, whose latitude is less than 67 or 68 Degrees, even allowing for the Effects of Refraction: And if the Credibility of the Testimony of these simple Indians be called in question, I can mention that of Mr. Norton, who was Governor at Churchill above twenty years, and had travelled almost a Year north-westward by Land with this Country Indians. This Gentleman has often affirmed the same thing of the Sun; and that in his whole journey he met with no Salt River, nor Tree, nor Shrub, but only Moss; and that he and his Retinue were reduced to such Extremity as to eat Moss several days; having nothing else that could serve them for Substenance but their Leather Breeches, which they eat up also. Now it will appear, from a just trigonometrical Computation, that Churchill being in Latitude 59°, and the Mine in Latitude 67°, and the Bearing N. W. the difference of Longitude between Churchill and the Mine is 17° 45′ (actually 11° 30′). But Wager River's Entrance being in Latitude 65° 20′, and 10 Degrees of Longitude east of Churchill, the Difference of Longitude between the Mouth of the River and the Mine is 27° 45′, and their Distance in the Arch of a great Circle, or their nearest Distance, no less than 700 Miles. (Actual distance, 900 miles.) From what I have here made out concerning this Mine, and the way to it, upon the Report of the Indians and of Governor Norton, it follows, even to Demonstration,

"1st. That neither Wager River, nor any other River or Sea, does extend so far westward, from any Part of Hudson's Bay in less than Latitude 65°, as to cross the Rout that lies between Wager River and the Mine. And,

"2dly, That if there be any Passage at all, it must run up so high northward, as to cross the Parallel of 67° on the East Side the Mine, and consequently must be frozen up, and absolutely unnavigable the whole Year."*

A brief reference to the map of Canada will indicate how nearly correct Captain Middleton was able to judge of the position of the Coppermine country. At the same time it is difficult to avoid the conclusion that Richard Norton, his informant, had either visited the country himself or had gained a very just idea of its position through his intimate knowledge of the Indian language and character.

In 1719 the directors of the Hudson's Bay Company ordered Mr. Norton, upon application of his mother on his behalf, a gratuity of £15 on account of having "endured great hardships in travelling with the Indians,"† doubtless on this journey to or towards the Coppermine country. With reference to this journey a Captain Caruthers, who was in the employ of the Hudson Bay Company, states in the Parliamentary Report of 1749, that he "himself carried Mr. Norton, who was afterwards Governor, and two Northern Indians, to Churchill, where he put them in a canoe; and the purpose of their voyage was to make discoveries, and encourage the Indians to come out to trade, and bring Copper Ore."‡

In the same Parliamentary Report, Alexander Brown, a surgeon who had been for six years in the Company's service, testified that the Indians "brought down the ore at the request of Governor Norton," and also "that he had heard the late

*A vindication of the Conduct of Captain Christopher Middleton in a late voyage on board His Majesty's Ship Furnace, by Capt. C. Middleton, London, 1743, p. 41.

†Report from the Committee Appointed to inquire into the state and condition of the Countries adjoining to Hudson's Bay, London Govt. 1749, p. 276.

‡Report from the Committee, 1749, p. 231.

Mr. Norton say that he had been at this Mine, and that a considerable quantity of Copper might be brought down."*

During the same time Captain Knight, who had been in charge of a number of the Company's posts on Hudson Bay, and who was himself the founder of Churchill, had also seen some of this copper ore and had become greatly interested in it, though there is also reason to suppose that he considered that it was associated with gold, or that gold occurred in the country. Arthur Dobbs says of him, that he had a great share in the Company's stock and that he pressed the Company to go upon the discovery and trade and had strong chests made to hold the gold he was to bring home.

In the spring of 1719, Captain Knight and his associates sailed from England in two ships, named the "Albany" and the "Discovery." Unfortunately, the expedition was wrecked on Marble Island and all the officers and crew were lost, although their fate was not definitely known until the year 1767, when their remains were discovered by Mr. Joseph Stephens of the Hudson Bay Company, who was in charge of a small vessel called the "Success," engaged in the whale fishery.

The account of the finding of the remains of Captain Knight and his men is given in very pathetic terms by Samuel Hearne,† how they lived on the island for a couple of years and used to go up to the top of the rock looking for someone to come and rescue them, and how, at last, only two remained and of these two one fell down and died and the other died in attempting to bury him.

After the unsuccessful and tragic voyage of Knight and Barlow no serious attempt was made to find the Coppermine country for some time, but the following references to it in Arthur Dobb's "Account of the Countries adjoining to Hudson's Bay," 1744, pp. 47, 48, 59 and 80, will show that it was not forgotten.

"Mr. Frost, who has been many Years employed by the Company in the Bay, both at Churchill and Moose River Fac-

*Report 1749, p. 226.

†Hearne's Journal, New Edition, Toronto, 1911; with introduction by J. B. Tyrrell, pp. 45-49.

tory, who was their Interpreter with the Natives, and travelled a considerable Way into the Country, both North-Westward of Churchill,——.

"He says when he was at Churchill, he travelled a considerable Way in the Country North-Westward of the River of Seals; that near the Rivers and Sea-coast, there was small shrubby Woods, but for many Miles, at least 60 farther into the Country, they had nothing but a barren white Moss upon which the Rain-Deer feed, and also the Moose, Buffalos, and other Deer; and the Natives told him, further Westward beyond that barren Country, there were large Woods. He was acquainted, when there about fifteen Years ago, with an Indian Chief, who traded at Churchill, who had been often at a fine Copper Mine, which they struck off from the Rocks with sharp Stones; he said it was upon Islands at the Mouth of a River, and lay to the Northward of that Country where they had no Night in Summer.

"The Company avoid all they can making Discoveries to Northward of Churchill,——.

"But tho' they are fully informed of a fine Copper Mine on a navigable Arm of the Sea North-westward of Whale Cove, and the Indians have offered to carry their Sloops to it, yet their Fear of discovering the Passage puts Bounds to their Avarice, and prevents their going to the Mine, which by all Accounts is very rich; yet those who have been at Whale Cove own, that from thence Northwards is all broken land, and that after passing some Islands, they from the Hills see the Sea open, leading to the Westward;——

"Churchill River, in Latitude 59°, a noble River, navigable for 150 Leagues, and after passing the Falls, navigable again to far distant Countries, abounding in Mines of Copper,——

"Scroggs, in his journey Northward in 1722 had two Northern Indians with him, who had wintered at Churchill, and told him of a rich Copper Mine somewhere in that Country, upon the Shore, near the surface of the Earth, and they could direct the Sloop so near it, as to lay her Side to it, and be soon loaden with it; they had brought some pieces of Copper from it to Churchill, that made it evident there was a Mine thereabouts."

About the same time an acrid discussion was carried on between Arthur Dobbs, and Captain Christopher Middleton, captain of the "Furnace," as to the honesty of the latter in endeavoring to find a North-West Passage in 1741-2, and while the main points in the discussion are of little interest, the disputants published four books which contain some useful information about Hudson's Bay and the adjoining country. The quotation from Captain Middleton, published on page .., is from one of these books. The following references to the Coppermine River also occur in them.

Edward Thompson, surgeon (of the "Furnace"), is quoted as stating:—

*"Likewise, the two Indians gave us an Account of a River or Straits, Salt-water and deep, a great Number of large black Fish, spouting up the Water, and that they were five Days in crossing it, and that there was a Copper Mine upon the Side of this River or Strait, and by the best Accounts I could gather from them, it was somewhere hereabouts, and when we left Brook Cobham, and sailed to the North-eastward, they told us, that that was not the Way to the Copper Mine, but were going from it."

And also:—

†"These two Indians left their Wives and Families, and came on board entirely to show us the Copper Mine before mentioned."

With regard to Richard Norton's journey, Arthur Dobbs makes the following statement:—

‡"For there are several Persons, now living, who know the exact Time of Norton's setting out upon his Travels, and the Time of his Return, who all agree, that Norton was a poor Boy, taken an Apprentice by the Hudson's Bay Company, and sent over to one of their Factories in Hudson's Bay. After he had served three Years of his Time, he became a tolerable Linguist for the Languages of those Nations that traded with the Hudson's Bay Company's Factors.—When Norton was about seven-

*A Vindication, 1743, p. 186.
†Loc. cit., p. 189.
‡Remarks upon Middleton's Defence, by Arthur Dobbs, 1744, pp. 24-25.

teen Years of Age, a Factory was first begun to be settled near Churchill River, in order to enlarge the Company's Trade; and Norton was pitched upon, tho' a Youth, to go in quest of a Nation of Northern Indians (he speaking their Language), to acquaint them there was a Factory settled at Churchill, for promoting a Commerce between that Nation and the Company. Norton set out in his Canoe, with a Northern Indian, the Middle of July, 1717, and went no farther to the Northward than the Latitude of 60 Degrees. He there left his Canoe, and travelled in-land in quest of this Northern Nation, took a great Sweep to the Southward of the West, and found them returning to their Winter Quarters. He engaged some of those People to travel with him to Churchill, where they all arrived about Christmas the same Year, after having endur'd a great many Hardships.—How does this Relation, which is well known to be Matter of Fact, tally with Captain Middleton's Story of the Indians' and Norton's travelling by Land to 68°, their seeing the Sun running round the Horizon for several Days together, especially Norton, who must have inverted the Order of Nature, by seeing the Sun above the Horizon for several Days together in Wintertime, when in 68°."

In the same book Dobbs quotes Edward Thompson and John Wigate, the surgeon and clerk of the "Furnace," as follows:—

*"Whereas it hath been reported by Capt. Middleton, that Mr. Norton, late Governor of Churchill, travelled from Whale Cove, in the Latitude of 62° off to 65° odd inland, without Interruption of any Lakes, Rivers or Streights, and could perceive no such Thing as any Inlet or Opening to the South Sea, etc.

"To confute this, it has been several Times reported by the said Norton, that so far as he travelled he saw nothing but broken Lands and Islands from 60° to the Extent of his Journey; and that the native Indians he had then with him gave him a very good Account of a Copper Mine upon the Side or Bank of a large River or Streight; and that a Person might easily go with a Ship or Sloop, and ly close to the side thereof, and fill their Vessel with the aforesaid Metal at Pleasure.

*Remarks, &c., pp. 146-7.

"Likewise the two Northern Indians that we took in at Churchill, the one named Nabiana, the other Iazana (tho' upon the Ship's Books they are call'd Clayhulla and Cloydiddy), gave me a particular and more affirmative Account than Mr. Norton's. They mark'd out upon my Table the Tract of Land or Confines of their Country, as far as they knew together with the Course of some remarkable fresh Water Rivers in their Country; but in particular they gave a very good and clear Account of a Copper Mine, which they generally used to go to once in two Years; and at this Copper Mine there is a large River or Streight, salt Water and strong Tides, Plenty of a large kind of black Fish, which by their description I imagine to be Whales; and that they were five days in crossing that salt Water in their Canoes; and that this River or Streight was so deep, that they could find no Bottom with a Deer Skin cut into very fine Thongs, and at least was an hundred Fathoms long; that the Course of this River run towards the Sun at Noonday, and this River appeared to me to be about the Latitude of 63°, or thereabouts; for they seemed, in our Voyage, to have more Knowledge of the Land near that Latitude than in any other Part of our Discovery; and when we sailed to the North-eastward of that Latitude, they told us we were going from the Copper Mine, and the River they spoke of.

"The Country these Nations inhabit in Summer, upon account of their killing Deer, they told me was all barren, high and rocky, and that they go inland in the winter to the Southward to catch Beaver and other Furrs. I had frequent Conference with these two Indians, who seemed to be well affected towards me, and were never better pleased than when I was writing a Vocabulary of their Language; by which I might be enabled to discourse with them more familiarly, and they were very eager of learning English.——

"Given under our Hands this 9th Day of April, 1743.

"EDWARD THOMPSON
"JOHN WIGATE."

Writing of Norton's trip northward, Captain Middleton again says:—

*"But this I averr, that he has very often told me, and not long since, that he went from the Factory in the Fall of the Year, which was sometime in August, and paddled along the Shore in a Canoe, with a Northern Indian man, and a Girl, for the Space of fourteen Days, before they quitted the Canoe; and travelled afterwards inland to the Northward of the West, about ten or twelve Days, and then met with the Northern Indians or some of them. Now could they be fourteen Days in paddling but twenty Leagues, from Churchill to Latitude of 60°, which is but one Degree? Twenty Miles a Day in a Canoe, is esteemed but easy Labour for him who paddles. Let us suppose they went but fifteen miles in twenty-four Hours, one Day with another; this gives two hundred and ten Miles in the Space of Time mentioned, which are 3° 30′, and makes the Latitude 62° 30′;——

"From all the Accounts I could get, and I have made the strictest Enquiry, the Northern Indian Nations live between the Latitude of 63° and 64°. The most particular Account I ever had, was after I came home from my last Voyage, and this was from the Indian Linguist, whom I had then with me, and at my Lodgings after my Return, till about Christmas, 1742, when he died. He had been several Winters and Summers among them, and said they were never less than three Weeks or 21 Nights, which is their way of reckoning, in coming to the Factory; but were much longer in going back (The Reason of this Difference of Time, is that in coming to the Factory, the Way is Frozen, but the Ice broken up when they return). As near as he could make it out, their Country lies in a strait Line with the Sun's setting in Summer (from Churchill) which must be about N.W. Now admit these Indians travelled but 20 Miles in 24 Hours, which to them is nothing when the Ground is frozen, this would make 421 Miles, and that Distance N.W. will give near 5° of Latitude, which added to that of Churchill, places these Northern Indians in Latitude 64° North; this agrees with all the Accounts I have heard, and with what Scroggs' Indian said. See his

*A Reply to the Remarks of Arthur Dobbs, by Captain C. Middleton, London, 1744, p. 26.

Account in Whalebone Bay; from whence they desired him to let them return home, as then being not above three or four Days' Journey from their own Country.*

"I all along understood, and do yet believe, that Mr. Norton continued that Winter and one Summer with these Northern Indians, and returned the Winter following, after having travelled throughout their Country, to engage as many as possibly he could, to come down and trade; and if this was the Case, he might very well have observed the Sun's going round several Days together, and the imputed Blunder falls to the Ground."†

A few years later, in 1748, at the request of Arthur Dobbs and others a Parliamentary Investigation was held into the conduct of the Hudson's Bay Company, and the following references to the Coppermine country, in addition to those already cited, appear in the Report of the Committee and in the evidence submitted.

Edward Thompson, who had been three years at Moose River in the Company's service as surgeon, said:—

‡"That he has heard the Natives talk of a Sea to the Westward, which, by their Accounts, is not far distant; and of a Copper Mine, which lay on the side of a Streight which takes them five Days in crossing; that they describe the Water of this Streight to be very deep, and that they could not reach the Bottom with Two Deer-skins cut into Thongs; And if a Sloop could be brought along-side this Copper Mine, they say they could fill it in a little time. And, by their Account, this Streight has a Communication both with the Bay and the South Sea.

"The Witness could not learn at what Distance this was from the Factory, nor did he inquire which Way the Tide sat; but the Indians said, that the Water was deep and salt, and there were great Fish spouting up in it."

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*Vid. Mr. Dobb's Remarks, p. 115.

†A Reply to the Remarks of Arthur Dobbs, by Captain C. Middleton, London, 1744, p. 26.

‡Report from the Committee appointed to inquire into the State and Condition of the Countries adjoining to Hudson's Bay, London. Govt. 1749, p. 223.

"Christopher Bannister, who had been Armourer and Gunsmith to the Hudson's Bay Company, and had resided in the Bay about 22 years, informed your Committee:—

*"That he had seen Copper frequently brought down by the Northern Indians, a Piece of which he produced to your Committee; and said, He had seen great quantities of it there; and was informed by a young Man, who is now at Hudson's Bay, that the Indians told him, that it was brought from a Mine, in Search of which the young Man would gladly have gone."

†"Mr. Alexander Browne, who has been Six Years in the Company's Service at Hudson's Bay as Surgeon, informed your Committee, that he has seen both Copper and Copper Ore at Prince of Wales's Fort in Churchill River, which the Northern Indians informed the Witness they brought from an Isthmus of Land, which lies by a Lake at the farthest Extent of their Country: That tis hard to ascertain the Distance from the Accounts of the Indians, but that tis judged to be about Three or Four hundred Miles: That he never heard the Indians say whether there was a Passage to this Place from the Bay by Water, but they informed him their River ran by it.

"That they bring down the Copper for Ornaments; and that they brought down the Ore at the Request of Governor Norton: But that the Witness does not know whether any of it was sent to England, or whether any Trial was made of it there: That he has seen about Four or Five Pounds of it, both before it was smelted, and after; and he takes it to be a rich Ore, but does not understand Metals. That he has heard of Lead Ore at Hudson's Bay, but never saw any.

"That he never saw the Indians smelt it; but they informed him, that the Earth was washed from the Ore by Showers, and that they smelt it on a Fire till it runs, and then beat it, it being very malleable; That he never heard of a Copper Mine on the large Arm of the Sea, but the Ore is brought down by Canoes to the open Sea; and that the Rivulet which washes the

*Report, &c., 1749, p. 225.

† Report 1749, p. 226.

said Copper is not known to have any Communication with Hudson's Bay, the Mine being about Fifteen Miles from the open Sea, by the Accounts of the Indians.

"That they might bring the Ore in their Canoes to Churchill River; But the Witness can't say whether the Company's Sloops could go within Fifteen or Sixteen Miles of the Mine, since there are frequent Shoals in those Seas; But Canoes may come down to meet the Vessels; for the Ice makes the Water so smooth, that a Canoe can live Thirty Leagues from Shore. That he apprehends the Indians come a little to the Northward of Whale Cove, which bear a Point or two to the West of the North from Churchill.

"That if the Indians were encouraged, they would bring great Quantities of Ore, as well as smelted Copper, to Whale-Cove; and that a Pound and a half of Ore would, in the Opinion of the Witness, produce a Pound of pure Metal. That if Persons were sent up to the Mine, they might smelt the Ore there; but they would labour under a difficulty for Want of Fuel, the Country producing no Wood; and what the Indians smelt, they do in small Quantities with Moss.

"That the Country about the Mine is only inhabited in the Fishing Season; and that he apprehends it produces Furs: And that he never heard the Company offer to trade with the Indians for Copper: That the Rivulet which runs by the Mine runs into the Sea; and that he apprehends there is a Communication betwixt this Sea and Whale Cove: That he has heard the late Mr. Norton (who was the first that brought the Northern Indians to trade, being sent among them for that Purpose by the then Governor) say, that he had been at this Mine, and that a considerable Quantity of Copper might be brought down: That the Indians will carry their Canoes, as the Witness believes, about Four or Five Miles over Land, but they often leave their Canoes and go within Land: That on Mr. Norton's being sent to the Northern Indians, a small Trade was carried on, which has been improved of late Years, but nothing to what it might be by giving the Encouragement of a greater Price: But Mr. Norton never told the Witness why the Copper Trade was not carried on."

*"Captain Carruthers, being examined, informed your Committee, that he had formerly been in the service of the Hudson's Bay Company, which he quitted thirty-five years ago.

"That he has heard a good deal of a Copper Mine to the Northward of Churchill River, the Indians speaking of it to the Interpreter while the Witness was by; but he understood no more than that it lay to the Northward of Churchill, and that the Governor was mighty fond of the Discovery, and made great Inquiries about it.

"That the Interpreter reported the Answers of the Indians to the Governor and Council, of which the Witness was one; and they described the Mine sometimes as a Gold Mine, sometimes as a Copper Mine; and that the Witness has seen Copper which was said to be brought from thence, but he does not know whether it was so or not; That the Governor was very earnest in this Discovery, which was always his Topic, and he took all Opportunities of making Presents to the Natives: And the Witness himself carried Mr. Norton, who was afterwards Governor, and Two Northern Indians, to Churchill, where he put them in a Canoe; and the Purpose of their Voyage was to make Discoveries, and encourage the Indians to come down to trade, and bring Copper Ore: That he can't recollect, that he ever heard how far it was to this Copper Mine; nor does he know whether there is an easy passage to it by Land, having never travelled by Land himself, nor heard of any Exepdition of that kind, except that undertaken by Norton and the Two Indians aforesaid."

In 1768 Richard Norton was dead, but his half-breed son, Moses Norton, had been appointed Governor of Fort Churchill in his place, and during that year some Indians brought in beautiful specimens of Copper from that fabled Copper country. Norton was so interested in these new specimens from a country of which he had already doubtless heard much from his father and others, that he took passage on the annual ship to England and laid before the Governors of the Company a project for what he believed to be the complete exploration of the country

*Report 1749, p. 231.

and a definite settlement of the question of whether there was available Copper within reach of the shores of Hudson Bay or not. It is interesting to note that the same ship which took Governor Norton to England had brought out William Wales and Joseph Dymond to observe the transit of Venus at Churchill.

In the following year Mr. Norton returned from England with authority to send out one of his clerks named Samuel Hearne to explore the Coppermine country. The following is an extract from the instructions of the Company as given by Hearne himself*:—

"From the good opinion we entertain of you, and Mr. Norton's recommendation, we have agreed to raise your wages to £— per annum for two years, and have placed you in our Council at Prince of Wales's Fort."

"Mr. Norton has proposed an inland journey, far to the North of Churchill, to promote an extension of our trade, as well as for the discovery of a North West Passage, Copper Mines, &c.; and as an undertaking of this nature requires the attention of a person capable of taking an observation for determining the longitude and latitude, and also distances, and the course of rivers and their depths, we have fixed upon you (especially as it is represented to us to be your own inclination) to conduct this Journey, with proper assistants.

"We therefore hope you will second our expectations in readily performing this service, and upon your return we shall willingly make you any acknowledgment suitable to your trouble therein."

Hearne was then a young man 24 years of age, and as soon as possible after Norton's arrival home he made preparations for the journey inland. On the 6th of November he left Churchill, or rather Fort Prince of Wales, at the mouth of Churchill River, in company with a few Chippewyan Indians and started north-westward on foot for the Coppermine, but he only got a short distance when the Indians left him and he was obliged to return.

*Hearne's Journey, New Edition. Toronto, 1911; with introduction &c., by J. B. Tyrrell, p. 50.

After a couple of months at home he again started out in the middle of winter and wandered over the Barren Grounds until the following autumn, when, being again abandoned by his Indians, he was obliged to return to his old home on Hudson Bay; but on the way home he had met an Indian Chief named Matonabbee, who offered to take him to the Coppermine River, and who afterwards showed that he was able to substantiate his offer by accomplishment; so, on the 7th of December, 1770, after having been home for only twelve days, he again started out on foot for the Coppermine River, and this time, thanks to the leadership of the great Indian whom he accompanied, he was able to reach the country that he was in search of.

Hearne knew nothing of mines or minerals, but, like many a man similarly equipped since his day, he was sent to report on a great mining property. Naturally, his report on the mine of copper is of little value, but in his book he has given an exceedingly interesting account of life among the Indians on the Barren Grounds in his time. What he has to say, however, is interesting, as it is the first account of the occurrence of the copper by an eye witness. His remarks are as follows*:—

"We arrived at one of the copper mines, which lies, from the river's mouth about South South East, distant about twenty-nine or thirty miles.

"This mine, if it deserves that appellation, is no more than an entire jumble or rocks and gravel, which has been rent many ways by an earthquake. Through these ruins there runs a small river; but no part of it, at the time I was there, was more than knee-deep.

"The Indians who were the occasion of my undertaking this journey represented this mine to be so rich and valuable, that if a factory were built at the river, a ship might be ballasted with the oar, instead of stone; and that with the same ease and dispatch as is done with stones at Churchill River. By their account the hills were entirely composed of that metal, all in handy lumps, like a heap of pebbles. But their account differed so much from the truth, that I and almost all my companions

*Ref., p. 24.

expended near four hours in search of some of this metal, with such poor success, that among us all, only one piece of any size could be found. This, however, was remarkably good, and weighed above four pounds. I believe the copper has formerly been in much greater plenty; for in many places, both on the surface and in the cavities and crevices of the rocks, the stones are much tinged with verdigrise.

"It may not be unworthy the notice of the curious, or undeserving a place in my Journal, to remark, that the Indians imagine that every bit of copper they find resembles some object in nature; but by what I saw of the large piece, and some smaller ones which were found by my companions, it requires a great share of invention to make this out. I found that different people had different ideas on the subject, for the large piece of copper above mentioned had not been found long before it had twenty different names. One saying that it resembled this animal, and another that it represented a particular part of another; at last it was generally allowed to resemble an Alpine hare couchant; for my part, I must confess that I could not see it had the least resemblance to anything to which they compared it. It would be endless to enumerate the different parts of a deer, and other animals, which the Indians say the best pieces of copper resemble: It may therefore be sufficient to say, that the larger pieces, with the fewest branches and the least dross, are the best for their use; as by the help of fire, and two stones, they can beat it out to any shape they wish.

"Before Churchill River was settled by the Hudson's Bay Company, which was not more than fifty years previous to this journey being undertaken, the Northern Indians had no other metal but copper among them, except a small quantity of iron-work, which a party of them who visited York Fort about the year one thousand seven hundred and thirteen, or one thousand seven hundred and fourteen, purchased; and a few pieces of old iron found at Churchill River, which had undoubtedly been left there by Captain Monk. This being the case, numbers of them from all quarters used every Summer to resort to these hills in search of copper, of which they made hatchets, ice-chissels, bayonets, knives, awls, arrow-heads, etc. The many paths that had

been beaten by the Indians on these occasions, and which are yet, in many places, very perfect, especially on the dry ridges and hills, is surprising; in the valleys and marshy grounds, however, they are mostly grown over with herbage, so as not to be discerned.

"The Copper Indians set a great value on their native metal even to this day; and prefer it to iron, for almost every use except that of a hatchet, a knife, and an awl; for these three necessary implements, copper makes but a very poor substitute. When they exchange copper for iron-work with our trading Northern Indians, which is but seldom, the standard is an ice-chissel of copper for an ice-chissel of iron, or an ice-chissel and a few arrow-heads of copper for a half-worn hatchet; but when they barter furs with our Indians the established rule is to give ten times the price for everything they purchase that is given for them at the Company's Factory."

After Hearne's visit in 1771 no white man visited the country for 50 years, until Sir John Franklin arrived at the head waters of the river, and then descended and made a survey of it from Point Lake to the Arctic Ocean. Franklin's account of the country is interesting. He states:

*"We rejoined our hunters at the foot of the Copper Mountains, and found they had killed three musk-oxen. This circumstance determined us on encamping to dry the meat, as there was wood at the spot. We availed ourselves of this delay to visit the Copper Mountains in search of specimens of the ore, agreeably to my instructions; and a party of twenty-one persons, consisting of the officers, some of the voyagers, and all the Indians, set off on that excursion. We travelled for nine hours over a considerable space of ground, but found only a few small pieces of native copper. The range we ascended was on the west side of the river, extending W.N.W. and E.S.E. The mountains varied in height from twelve to fifteen hundred feet. The uniformity of the mountains is interrupted by narrow valleys, traversed by small streams. The best specimens of metal we procured were

*A Journey from Prince of Wales Fort on Hudson's Bay to the Northern Ocean. By Samuel Hearne, New Edition. Toronto, 1911, with Introduction and notes by J. B. Tyrrell, pp. 194-199.

among the stones in these valleys, and it was in such situations that our guides desired us to search most carefully. It would appears, that when the Indians see any sparry substance projecting above the surface, they dig there; but they have no other rule to direct them, and have never found the metal in its original repository. Our guides reported that they found copper in large pieces in every part of this range, for two days' walk to the north-west, and that the Esquimaux come hither to search for it. The annual visits which the Copper Indians were accustomed to make to these mountains, when most of their weapons and utensils were made of copper, have been discontinued since they have been enabled to obtain a supply of ice-chissels and other instruments of iron by the establishment of trading posts near their hunting grounds. That none of those who accompanied us had visited them for many years was evident, from their ignorance of the spots most abundant in metal.

"The impracticability of navigating the river upwards from the sea, and the want of wood for forming an establishment, would prove insuperable objections to rendering the collection of copper at this part worthy of mercantile speculation."*

Among the members of Franklin's party was Sir John Richardson, the great naturalist, and his account of it is much more detailed than that given by his chief and is here appended:

"The Copper Mountains appear to form a range running S.E. and N.W. The great mass of rock in the mountains seems to consist of felspar in various conditions; sometimes in the form of felspar rock or claystone, sometimes coloured by hornblende, and approaching to greenstone, but most generally in the form of dark reddish-brown amygdaloid. The amygdaloidal masses, contained in the amygdaloid, are either entirely pistacite (Epidote), or pistacite enclosing calc-spar. Scales of native copper are very generally disseminated through this rock, through a species of trap tuff which nearyl resembled it, and also through a reddish sandstone on which it appears to rest. When the felspar assumed the appearance of a slaty claystone, which it did towards the base of the mountains on the banks of

*Narrative of a Journey to the Shores of the Polar Sea in the years 1819, 20, 21, and 22, by John Franklin. London, 1823. 4to, pp. 340-1.

the river, we observed no copper in it. The rough and in general rounded and more elevated parts of the mountain, are composed of the amygaloid; but between the eminences there occur many narrow and deep valleys, which are bounded by perpendicular mural precipices of greenstone. It is in these valleys, amongst the loose soil, that the Indians search for copper. Amongst the specimens we picked up in these valleys, were plates of native copper; masses of pistacite containing native copper; of trap rock with associated native copper, green malachite, copper glance or variegated copper ore and iron-shot copper green; and of greenish grey prehnite in trap (the trap is felspar, deeply coloured with hornblende), with disseminated native copper; the copper, in some specimens, was crystallized in rhomboidal dodecahedrons. We also found some large tabular fragments, evidently portions of a vein consisting of prehnite, associated with calcareous spar, and native copper. The Indians dig wherever they observe the prehnite lying on the soil, experience having taught them that the largest pieces of copper are found associated with it. We did not observe the vein in its original repository, nor does it appear that the Indians have found it, but judging from the specimens just mentioned, it most probably traverses felspathose trap. We also picked up some fragments of a greenish-grey coloured rock, apparently sandstone, with disseminated variegated copper ore and copper glance; likewise rhomboidal fragments of white calcareous spar, and some rock crystals. The Indians report that they have found copper in every part of this range, which they have examined for thirty or forty miles to the N.W., and that the Esquimaux come hither to search for that metal. We afterwards found some ice-chisels in possession of the latter people twelve or fourteen inches long, and half an inch in diameter, formed of pure copper.

"To the northward of the Copper Mountains, at the distance of ten miles in a direct line, a similar range of trap hills occurs, having, however, less altitude. The intermediate country is uneven, but not hilly, and consists of a deep sandy soil, which, when cut through by the rivulets, discloses extensive beds of light-brownish red sandstone, which appears to belong

forming a rugged ridge about two hundred and fifty feet high."

In the same year, 1821, Franklin and Richardson found trap-rocks of the copper-bearing series eastward along the Arctic Coast for nearly two hundred miles, or as far as the east side

*Narrative of a Journey to the Shores of the Polar Sea in the years 1819, 20, 21, and 22. By John Franklin. London, 1823. 4to. pp. 528-30.

SKETCH MAP OF COPPERMINE RIVER DISTRICT

to the new red sandstone formation. The same rock having a thin slaty structure, and dipping to the northward, forms perpendicular walls to the river, whose bed lies a hundred and fifty feet below the level of the plain. The eminences in the plain are well clothed with grass, and free from the large loose stones so common on the Barren Grounds, but the ridges of trap are nearly destitute of vegetation.

"Beyond the last-mentioned trap range, which is about twenty miles from the sea, the country becomes still more level, the same kind of sandstone continuing as a subsoil. The plains nourish only a coarse short grass, and the trees which had latterly dwindled to small clumps, growing only on low points on the edge of the river under shelter of the high bank, entirely disappear. A few ranges of trap hills intersect this plain also, but they have much less elevation than those we passed higher up the stream.

"The river in its section of the plain, as far as Bloody Fall, presents alternately cliffs of reddish sandstone, and red-coloured slaty indurated clay or marl, and shelving white clay banks. At Bloody Fall, the stream cuts through a thick bed of dark, purplish-red felspar rock, similar to that observed at the Rocky Defile, and associated, as at that place, with a rock composed principally of light red felspar and quartz, but which is probably a species of red secondary granite. At the Bloody Fall, the felspar rock is covered to the depth of six or seven hundred feet with a bed of greyish white, and rather tenacious clay, which being deeply intersected with ravines, forms steep hills. Nearer the sea, the river is bounded by very steep cliffs of yellowish-white sand; and on the sea-coast, the above mentioned red granite reappears on the west bank of the river, forming a rugged ridge about two hundred and fifty feet high."

In the same year, 1821, Franklin and Richardson found trap-rocks of the copper-bearing series eastward along the Arctic Coast for nearly two hundred miles, or as far as the east side

*Narrative of a Journey to the Shores of the Polar Sea in the years 1819, 20, 21, and 22. By John Franklin. London, 1823. 4to, pp. 528-30.

of Bathurst Inlet, though no copper or copper-ore seems to have been found in them.

On Franklin's second journey in 1826 Richardson recognized the existence of rocks of similar character at a number of points along the Arctic Coast for 200 miles west of the Coppermine River.

With regard to the character and age of some of these rocks Sir John Richardson says:—*

"The quartz rock beds acquire occasionally a pistachio-green colour, as if from the presence of epidote. A similar stone occurs at Pigeon River on the north shore of Lake Superior; and the limestones and sandstones of the latter district, with their associated trap rocks, as at Thunder Mountain, correspond in most respects with those between Cape Parry and the Coppermine River; and consequently, if we can rely on lithological characters, they may be considered as the oldest members of the Silurian series, or as the rocks on which that series is deposited, to which epoch the Lake Superior formation has been assigned."

From the description quoted above it would appear that the rocks on the Coppermine River are similar to the Copper-bearing rocks on Lake Superior, and that the conditions under which the copper occurs are also similar to them under which it occurs on Keewenaw Point on the south shore of Lake Superior. Speaking broadly, these rocks would appear to indicate a repetition to the north of the great Archean protaxis of the conditions which have prevailed on Lake Superior to the south of it.

Since Franklin and Richardson visited, mapped and described this region, very little attention has been paid to it, though Thomas Simpson and John Rae both crossed the Coppermine River, and make mention of it in their Journals.

The traps and associated rocks may cover a very much larger area than we know of at present, for, in 1903 I found them on the north shore of Doobaunt Lake, and on the Doobaunt River below the Lake. As late as 1902 the late David Hanbury ascended Coppermine River as far as the portage to Great Bear Lake in his journey from Hudson Bay to the Mackenzie River,

*Arctic Searching Expedition, by Sir John Richardson. London, 2 Vols., 1851, Vol. I., p. 283.

and he has mentioned in his book that one of his men named Sandy, while tracking up the river, "was nearly tripped up by a chunk of Native Copper on the shore. It weighed about twelve pounds."*

Though Hanbury gives us little or no information about the copper-bearing rocks in the immediate vicinity of the Coppermine River, he gives us very positive information about those rocks, and the occurrence of the metal in them, in and around Bathurst Inlet and Melville Sound, 175 miles east of the Coppermine River, substantiating Richardson's description of the country, and adding to it evidence of the presence of native copper.

The following is his description of the rocks and the occurrence of copper:

"On the 16th (of June, 1912), we reached Barry Island, which one of my Eskimo had described as the best place for copper. He now said copper was more plentiful on an island six or eight miles north of Fowler Bay. However, two pieces of native copper were found in the evening.

"The next day we searched for copper on the north-west shore of the island.

"The main rock of the island is a fine-grained basalt which Dr. Flett described as granular, holocrystalline, and non-porphyritic, and a good dead decomposed. The rock, although hard, is easily broken in all directions by a tap of the hammer. The summit of the island is, however, formed of a rock of the character of No. 6, which is described as coarse-grained ophitic dolerite with plagioclase and augite, and perhaps a few grains of olivine. The ophitic structure is very perfect.

"The underlying basalt dips west at an angle of about 25 degrees, and it is in this rock that the native copper occurs. The copper is plentiful, for the quantity we obtained was found after but a brief search, and on a neighbouring island, Kun-nuyuk, a mass of copper had just been found, so large that a man

*Sport and Travel in the Northland of Canada, by David Hanbury, 1904, p. 206.

could hardly lift it. There also copper is often found in the tide-way. The whole of the lower levels on Barry Island are covered with debris from the basalt, and where the rock has been disintegrated by weathering, copper has fallen out, so that flakes of the metal may be found along the sea-shore. In many places, too, green patches indicate that nuggets or flakes of copper have recently fallen out from their matrix.

"The copper-bearing rock also contains crystalline quartz, some of which forms beautiful amethystine veins, of which some specimens were taken.

"This island, Barry Island or Iglor-yu-ullig, is several miles in length, and perhaps three or four miles across. The island to the south-south-east, Kun-nu-yuk, is still larger, besides which there is an island to the south-west which has given much copper, and there are copper-yielding islands to the north. The copper-bearing formation holds good everywhere except on the summit cappings of the islands.

"On the 23rd, on our way across Bathurst Inlet, we approached a flat-topped precipitous island very much resembling a kopje.

"About five miles beyond this limestone island we passed a small basaltic island on which two pieces of copper ore were picked up. It seems as if copper is to be found wherever this basalt occurs.

"With the exception of some precipitously-cut rocks near our camp, this island is formed of the same partly-decomposed basalt as Barry Island. It is described as fine-grained, granular crystalline, decomposed basalt.

"Although we did not find so much copper here, the green marks on the rocks were more numerous, but we did not spend an hour altogether in the search. One of our Eskimo knew of a large mass of copper on the south-west shore of the island, which he stated to be as much as five feet in length, and three inches thick. It protruded from the rocks under the water, it was said, but there was too much ice for us to find the copper. A piece of quartz with copper ore and native copper was picked

up on the seashore. Another specimen of the copper-bearing rock here is a decomposed basalt, fine-grained, and not unlike No. 15, but vesicular.

"On the 27th we rested at the north-west point of Lewis Island, where we again found the copper-bearing basalt, and accordingly we commenced a search that resulted in our collecting about 2 lbs. weight of copper. The metal appeared to be very persistent in its occurrence in the partly decomposed basalt of which all the islands we passed that day consisted. The flakes of copper seemed to be always vertical when in their rock matrix. The rocks of this island, where they are not disintegrated, are well smoothed by glacial action, and the striæ are numerous and distinctly trend south and south-east."*

An important addition to our knowledge of the copper-bearing rocks of the northern coast of America has just been brought to my attention by Dr. James Douglas, of New York, and I am permitted to publish it through the kindness of the Secretary of the American Museum of Natural History. The information is contained in a letter from Mr. V. Stefansson, dated Langton Bay, July 1st, 1911, and addressed to Dr. H. C. Bumpus, Director, American Museum of Natural History, New York City. Mr. Stefansson writes as follows:—

"That copper was to be found on the Coppermine River has been generally known for more than a century; we found, however, that even the Eskimos nearest the river, while they pick up some copper on the banks occasionally, depend chiefly on the richer deposits north of Dismal Lake. Neither of these regions is rich in native copper, however, compared with the mountains north-east of Prince Albert Sound." (on Victoria Land).

This is the first record of the occurrence of native copper or the copper-bearing rocks on any of the large islands in the Arctic Ocean, and as Prince Albert Sound is probably accessible to ocean-going ships by way of Behring Sea, the locality might be much easier to explore and mines might be much more

*Sport and Travel, pp. 264-6.

readily developed than in the districts on the mainland in the vicinity of the Coppermine River.

Judging from the evidence here presented, the existence of a great copper-bearing area on the Arctic Coast of America near the Coppermine River is certain, and it is also reasonably certain that that area is very much more extensive than the copper-bearing area south of Lake Superior, extending, as it does, from Victoria Land and the hills west of the Coppermine River to the shores of Bathurst Inlet far to the east, but whether native copper will be found anywhere as plentifully distributed or in such rich segregations as on Keewenaw Point, is yet quite uncertain. As the copper-bearing area in Northern Canada is larger it is quite possible that the mineral deposits may be similarly larger, and it is worth while for the Canadian people to find out whether they have in this far northern country a great reserve of copper ore for the use of themselves and the world when the mines that are now being worked shall become depleted. It may seem foolish for us to spend money at the present time to determine the existence of bodies of ore which we cannot use, but copper is one of the most useful metals in the world to-day, and it behooves a nation like an individual to study its ore reserves in order that it may deal with them wisely, and have them developed in such a way that they will bring the greatest benefit to the people. Therefore, I say that we Canadians, knowing that we possess an area of potential wealth in copper in that far northern country, should examine it carefully and find out whether we have a natural asset there that, if intelligently used, will add greatly to the wealth of the nation, or whether we are prepared to hand over that possible asset without knowing whether it is valuable or not, to private individuals, who, by the expenditure of a little capital and energy, may make enormous fortunes as a result of our negligence.

EDITOR'S NOTE.—When presenting the above paper the author exhibited specimens of native copper which had been brought by Eskimos from the Coppermine River. Some of the implements were the property of his brother, Mr. J. W. Tyrrell, of Hamilton, who obtained them in 1900 on his trip across the Barren Lands from Great Slave Lake to Hudson Bay; while others were obtained by Mr. Alston at Churchill from Eskimos who resorted there to trade.

MINING LAWS.

By Horace V. Winchell, Minneapolis, Minn.

(*Annual Meeting, Toronto, March,* 1912.)

The question of national mining laws is of special interest just now in both Canada and the United States. Attention has been widely called to the many defects and general insufficiency of existing statutes, and wherever the matter has been discussed, the need for revision has been admitted. In the United States during the past decade there has been frequent agitation of the subject. Public officials connected with the administration of our land and mining laws have urged legislation along certain lines; the Director of the Geological Survey, and the Secretary of the Interior have discussed it in their annual report; and the matter has even engaged the attention of Presidents Roosevelt and Taft in messages to Congress. Associations and societies of various descriptions after due consideration have passed resolutions demanding this or that measure of relief, and in some cases committees have been appointed for the purpose of making recommendations as to the principles to be followed in new legislation. Thus, a few years ago a committee of prominent mining engineers, among whom were Mr. John Hays Hammond and Dr. James Douglas, united in a report upon this subject to the Government at Washington; but nothing came of it, and so far as I can learn, the report was never even published. More recently the matter has again been agitated and committees for its consideration have been appointed by the American Mining Congress and the Mining and Metallurgical Society of America.

We, in the United States, might as well profit in this matter by the very sensible and systematic method which has been adopted in Canada to facilitate the proper settlement of

this most important question. Here, as I am informed, a committee of engineers and lawyers has been selected by the Canadian Mining Institute to draft a bill for a Canada Mines Act, and to present the same for consideration and adoption by the Dominion Parliament. In other words, Canadians have adopted a course to procure laws framed by experts; and none can doubt that statutes thus prepared are in every way superior to enactments whose subject matter is prepared by theoretical political economists on the one hand or by agitators and professional politicians on the other. I wish, therefore, at the outset to commend the Canadian Mining Institute for their very wise procedure in this matter and admonish its membership not to weary in well-doing, nor to be disheartened at slow progress. When you have accomplished what you have set out to do you will not only have that pleasant sense of satisfaction which succeeds the consciousness of duty worthily performed, but you will have made an investment of time and labour which will return a thousand-fold in actual wealth and prosperity. For that country which is willing to be guided as to the handling and development of its mineral resources by the crystallized policies of its mining engineers is the country whose mining industry will be at once the best managed and the most productive of material blessings for the people as a whole.

The mining laws of a country are those legislative enactments or customs established by precedent which control the acquisition and tenure of mining rights and property, in contradistinction to "mining regulations" which have to do with the methods and appliances used in operating mines.

The principles underlying the mining laws of various countries have been found susceptible of classification into two groups: (1) "The *Concession* system under which the state or a private owner of mining property has the right to grant concessions or leases of such mining property to individuals or corporations at discretion, or under certain general restrictions. (2) The *claim* system, under which any individual, under certain general specified restrictions, generally as to nationality and colour, has the right to locate on discovery or

otherwise certain limited areas of ground, and under certain conditions to hold, work and dispose of the same.''*

Under the Concession system the right to grant lies with the owner, and it is said that five-sixths of all the mining areas of the old world are held under it; under the Claim system the right to claim mining ground lies with the locator or discoverer. The latter is the system underlying the laws of Canada and the United States as well as South Africa and Australia; but there are fundamental differences in these countries as to the nature of the possessory right and the character of title finally obtained.

Originating in the ancient proprietary rights of kings and feudal lords to the minerals of the ground, the Concession system still prevails in more or less modified form under all the ancient civilizations of the world. Its chief advantage is in the retention by the state of the right to select and control the operations of its concessionaires, thus securing proper capitalization and development, good management, economical use of raw material and the payment of rental or royalty.† To this system there have been objections as follows:

(1) That it places unduly large property control in the hands of a few men, and takes from the labouring man the chance of sudden wealth; (2) that by destroying competition in the sale of mines it places in the hands of the holders of large concessions the power of unlimited capitalization and speculation; (3) that it leads to the tying up of large areas of mining ground and thus restricts the employment of labour and the mineral production of the country. To these objections it may be answered that a relatively small number of men will always have control of the money with which to buy and develop mining property no matter how it be granted; that the government may easily regulate the capitalization of its leases; and that a large, strong corporation is usually better prepared to thoroughly prospect its territory than the unaided though far more numerous prospector. If diligent prospecting is required as a condition in the concession, the system of preference rights to explore large areas with the further right to

* Mining Law of the British Empire, C. J. Alford, London, 1906; p. 1.
† Alford, *loc. cit.* p. 2.

take out leases of limited area would seem to present many practical advantages for new and unexplored countries.

The Claim system grew out of conditions in early mining days in the United States and Australia. The argonaut horde which invaded California in 1849, and a few years later rushed to Australia, were in many cases allowed to make their own local rules as to size of claim, method of discovery, staking, recording and obtaining title. In the United States the usages thus established were later sanctioned by Congressional enactment which grew into our present system of mining law, and also served to greater or less extent as a model for Australia and other modern nations. This system, "however necessary in the peculiar circumstances of its inception, should have been altered as soon as changing circumstances permitted," but instead it has been patched and interpreted by judicial decision until the United States has to-day the most wretchedly inadequate and antiquated law with which a great country is anywhere afflicted. Instead of fostering the mining industry the law as it now stands and as interpreted by the judicial and executive branches of the government creates confusion, entails unnecessary expense, causes waste and retards development.

Two fundamental principles are common to the mining laws of all countries: (1) The right of the mine-holder to a perfectly secure and indefeasible title to his property so long as he fulfills certain specified conditions entirely within his own control, and (2) the right of the state or other landlord to certain rents, royalties or taxes on the property or its output and to the reasonably constant operation of the mine.

In the power of the government to fix the rate of royalty or taxes lies also the ability to promote or to discourage prospecting and mining. If the chief aim of the government is the development of national resources and the increase of general prosperity and business, its policy for the disposition and holding of its mineral lands will be most liberal. If there is a desire to enrich the public treasury directly by means of a revenue from taxes upon mines the result may be a rapid

decline of the mining business, and a shifting of the population to more favoured communities.

It is frequently stated, and truly as I believe, that the principal factor in the growth and development of the United States and Canada has been the liberality of their policy for the distribution of their public domain. Freely, or at a nominal consideration, homesteads and mines have been offered to all who chose to come and settle, to develop and use. If during the past fifty or seventy-five years the policy of conservation as now advocated by its most ardent proponents had been expressed in our statutes North America would be for the most part as little developed as Alaska. There would be a line of settlement along the Atlantic and a few fishing hamlets on the Pacific. The interior of the country would still be to a very large extent bottled up and conserved; and we should perhaps be still importing the bulk of our copper and iron as we are of our tin, platinum, potash and sulphur.

To speak to an audience of mining men of the importance of a liberal mining law is like carrying silver to Cobalt or copper to Butte, but since these remarks may find a wider audience a few words upon the extent of our mining industry may not be out of place. First, with reference to the United States. The annual products of the mines of the United States now exceed $2,000,000,000 in value. They contribute 65 per cent. of the freight traffic of the country. The industry employs over a million men at the mines and twice that number in handling, transporting and manufacturing the products.* The total value of our metallic products during 1907 was $900,000,000; of mineral fuels, $788,000,000; and of non-metallic mineral products, other than fuels, more than $378,000,000. During the year we imported mineral products to the value of $255,000,000 and exported mineral products to the value of $340,000,000. From the beginning of coal mining in this country in 1814 to the close of 1907, there were mined nearly seven billion (6,865,000,000) tons. Adding to this the one-half additional supposed to have been wasted in mining,

*Report of the National Conservation Commission, Vol. I., p. 95, Washington, 1909.

gives a total of more than ten billion tons taken from the supplies originally available. The amount of easily accessible and available coal in the United States, exclusive of Alaska, is estimated as 1,400,000,000,000, while the total including Alaskan reserves of 150,000,000,000 tons, and the coal not easily accessible is, perhaps, double this amount, and the country is as yet but partially explored. It may be remarked in passing that since the United States is now mining about 500,000,000 tons of coal annually we would appear to have a coal supply sufficient for about 6,000 years at the present rate of consumption, even without borrowing or buying from the enormous coal bins of Canada. Can anyone doubt that the provisions of the laws governing the disposition of the fifty million acres of coal land still remaining in the hands of the government is a matter of importance to a nation with an annual coal consumption of five tons per capita?

Figures are wanting as to the quantity and value of other mineral products estimated to remain within the unappropriated public domain. The land area of the United States excluding Alaska and the insular possessions, is about 3,000,000 square miles, or 1,920,000,000 acres. Of this area over half is arable, and a little less than half is occupied as farm land. About two-thirds of the land has passed into private holdings. Of the original acreage there remained on July 1, 1908, 387,000,000 acres, or about one-fifth open to entry. Nearly all of this is arid or otherwise unsuitable for settlement by families. There are also about 235,000,000 acres of national forests, national parks, and other lands reserved for public use. Of the entire area of 1,920,000,000 acres there remains unalienated about 622,000,000 acres or nearly *one-third* within which valuable minerals may still be discovered. Is it not a matter of vast importance to provide most carefully for the exploration, disposition and development of this vast empire? In what direction can the fostering care of government be more profitably and properly extended? And when we take into account Alaska with its undeveloped area of about 360,000,000 acres and our island possessions with 90,000,000 acres more is it not clearly one of the largest questions before the public at the present time?

In Canada the percentage of unappropriated public domain is larger than in the older country to the south thereof, and there is yet ample time to avoid the mistakes of omission and commission of the United States. With a total area of 2,118,814,000 acres, you have still in the hands of your Provincial and Dominion governments much the larger part of your acreage. Your annual production of minerals is valued at over one hundred million of dollars. At the present rate of increase it may easily amount to five hundred million dollars by 1950. Can your engineers find any more truly national work than to aid in the framing and adoption of the best possible laws for the protection and encouragement of the mining industry? Is it not apparent that there is a very close connection between mining laws and that conservation idea so dear to the imagination of the majority of our people to-day? If the true aim of conservation be "maximum use with minimum waste" is it not evident that to be consistent with this theory, mining laws must be liberal as to opportunity and inducement for the individual or corporation, and at the same time as scrupulous and exact in supervision and scientific regulation as the conditions of industry and the laws of political economy will permit? If the terms and conditions for acquiring mining property be so difficult as to materially restrict the number of prospectors or development companies there will be far less than "maximum use"; and if no right of supervisory control is retained by the government there will seldom be "minimum waste." The best code of mining laws will inevitably aid in the development of natural, mineral resources and at the same time have a tendency toward the right species of conservation, as contradistinguished from that variety of it which seems to aim at disuse, stagnation and paralysis.

In many particulars the present mining law of the United States is admittedly a failure, and in other respects it has both its critics and defenders. I propose to mention briefly some of its defects, and some possible amendments, not because there seems to be any danger that our worst faults will be copied by others, but in the way of general illumination of a question which is not always clearly understood even by our own people.

Briefly stated, the United States mining law, known as the Act of 1872, provides for location by discovery; possession perpetuated by annual assessment work; and title in fee simple to the surface and minerals, obtained after the expenditure of a certain amount of money, by the payment of $5 per acre, and the observance of certain formalities as to survey, etc. The metal mining laws do not apply to all of the states. They are made applicable to the western states and territories with the exception of Michigan, Wisconsin, Minnesota, Missouri, Kansas and Texas. Mining locations are not recognized in the states east of the Mississippi river, nor is there in any state legal authority permitting one man to prospect or mine beneath the surface of ground owned by another without the latter's consent. To this statement there is one important exception, and that lies in what is called the "apex law" under which the owner of the outcrop of a vein in mining claims, has the right to follow and mine the vein on its downward course beneath the surface of a claim owned by another. "This law has proven more productive of expensive litigation than of economical mining, and in many of the more recently established and more progressive mining districts has been made inoperative either by common agreement or by compromise between adjoining owners."* Placer mines are likewise located by discovery and held by annual work and acquired by purchase in fee-simple forever. Known veins within placer locations must be declared and paid for separately or else they are excepted from the placer patent and can be located by others in "lode claims." All veins on placer ground not known to exist at the time of application for patent belong to the grantee, but without extra-lateral or apex rights. If an applicant for a placer patent can be shown to have had knowledge of a valuable lode within his lines prior to the making of his patent application, his title as to that vein may be cancelled for fraud at any time upon application of a contesting locator. There is no limit to the time for such contests and they are still being brought in some cases 20 years after placer patent. The law is very defective on this point; for it frequently happens that veins discovered to-day

*Thirty-Second Annual Report, Director U.S. Geol. Sur., p. 15, Washington, 1911.

have a value by reason of improved transportation facilities or metallurgical processes although these same veins were of no value whatever when the placer claim was located and patented. The owner of such a claim is sometimes put to the expense and annoyance of defending such contests repeatedly since there is no limit to the number of contestants. The law should be amended so as to make it impossible to attack a placer patent on such charges after a reasonable term of years. Another absurd feature of the placer act is that providing for the location of oil, gas, iron ore and other deposits in the same manner as auriferous gravel. Coal lands are sold by the government upon an appraised valuation, and the amount of land that may be legally acquired is limited for an individual to 160 acres and for an association to 640 acres. Tracts of such limited area do not often justify the installation of the most efficient equipment, and economical operation is therefore impossible under the terms of the very law which was expressly designed to promote economy and prevent monopoly.

Under the present United States law there is no general system of separation of surface from mineral rights, no leasing of mines from the government, no payment of rental or royalty (except in connection with a tax upon earnings of corporations) and no Federal supervision or control after location and patent. Taxes are paid to the state and county, and mining regulation is attempted by many states. Unfortunately there is no uniformity of principle and practice as to these matters, nor any stability nor assurance of permanence in any state either as to method of operation required or basis of taxation.

Although it has been successful elsewhere and has much to recommend it, the government leasing system has never met with much favour in the United States. There is not at present strong opposition to grants in perpetuity by the government, although the leasing system has been recommended by some organizations and public officials. There is a hesitancy to create more bureaus because bureaucratic administration is not popular with those who have tried to transact business with many of them.

Aside from the generally condemned apex law, there are two or three features of our present system which should be speedily remedied. The first is that provision of the law requiring a discovery of valuable mineral before location. There is really no sense in such a requirement. What seems valuable to one man is often worthless to another; and what is of no value whatever to-day may be worth a million in a year or two. Moreover, it sometimes requires a year's work and a shaft several hundred feet deep before the actual discovery of ore, even though the surface indications give ample promise of its existence below. Every mining engineer and geologist knows that many ore deposits have no value whatever immediately upon the surface of the ground. Why not allow a prospector to stake out his mining claim wherever he chooses on the public domain, and hold it so long as he performs the required amount of development work?

Another defect in our present law is that permitting a prospector to locate an indefinite number of mining claims and to hold them without actually doing his assessment work. Many promising districts are kept from becoming hives of industry and producers of mineral wealth by the tying up of their territory in this way. The prospector should be restricted in the number of his locations, and real development work should be exacted.

The last important defect in the United States and Alaskan mining and land law to which I wish to call attention is the lack of any provision for appeals to the courts from the decisions of administrative officers. It is contrary to the general spirit of our institutions and an anomaly in constitutional government to take away from any citizen property rights to which he considers himself justly entitled under the law, by the mere fiat of an appointed government official who is here to-day and gone to-morrow. To place in the hands of such officers the final dicta in matters involving property valued at hundreds of thousands of dollars, and to provide no method of appeal to any duly constituted non-political judicial tribunal is not only to subject the said officials to great and unnecessary tests of moral courage and fidelity, but to require in them the

qualifications of superior judges and experience in the interpretation of the law which many of them cannot be expected to possess. Serious injustice may be done without any remedy at law to the defeated applicant. In the interests of justice, provision should be made for appeals in important cases and perhaps, in all cases from decisions of the Commissioner of the General Land Office or the Secretary of the Interior to some court of competent standing and jurisdiction, whose decisions could and would be accepted by the public and the interested parties as justified by the law and the evidence. I am gratified to notice that this point in Canada has been carefully covered in the recommendations of the Committee on Mining Law.

A comparison of the mining laws of the United States with those of other English speaking countries will disclose a fundamental difference in the underlying theory of the proprietorship of minerals, and hence in the attitude of the courts upon the subject as reflected in their decisions. Recent publication of a report upon the "Mining laws of Australia and New Zealand,"* has caused considerable discussion because of the fact that its recommendations have been to a certain extent adopted by other government officials in their annual reports and public addresses. This report apparently assumes a similarity between British laws and those of the United States in certain respects where actually a wide difference exists.

"Neither regalian right, nor anything similar, has ever existed in or been asserted by the United States.† While it has sovereign authority, and the power to enact such statutes as congress in its wisdom sees fit, within the limits of the constitution, its right is dependent upon and controlled entirely by statute.‡ Furthermore: "A distinction exists, and should be observed between ultimate ownership and right to govern on the one hand, and the exercise of regalian right, after possession and title is parted with, on the other. The former exists in the

* Bulletin 505 U. S. Geol. Survey, by A. C. Veatch, with a preface by Walter L. Fisher, Washington, 1911.

† There is a possible exception to this statement in the case of lands owned by some of the original thirteen states, and never controlled by the federal government.

‡ Snyder on Mines, Vol. I., p. 15.

United States, and the latter does not. The ownership, as well as the manner of exercising control, of mineral lands is regulated in the United States by statute."*

"The fundamental principles of the common law of England were to a certain extent ingrated into our legal system when we separated from the mother country and was and still is the rule of action in the absence of legislation. As a general rule, under the common law, minerals were the property of the owner of the land, the property in the surface carrying with it the ownership of everything beneath and above it.† Wherefore the ownership of the surface was the best *prima facie* title to the ownership also of the mines.‡ This *prima facie* ownership continued until rebutted by showing either (1) that the land contained 'royal mines'; or (2) that it was subject to some particular custom that defeated the *prima facie* ownership, as in the case of the tin mines of Cornwall and Devon and the lead mines of Derbyshire; or (3) that the ownership of the mines and minerals had become in fact, from divers causes several and distinct from the ownership of the soil and surface."¶

By the term "royal mines" was meant mines of gold and silver. These belonged exclusively to the crown, by prerogative, although in lands of subjects. In this respect the rule was the same as under the civil law. It was at one time contended that mines or mineral deposits containing the baser metals in combination with other gold or silver were royal mines. This contention, however, was set at rest by statutes enacted during the reign of William and Mary,§ wherein it was declared that no mine should be deemed royal by reason of its containing tin, copper, iron or lead in association with gold or silver. Thus, those mines only came to be classed royal in which were found the precious metals in the pure state. Briefly stated, the regalian right to mines, as recognized in England was confined to those of the precious metals, gold and silver. The baser

* Lindley on Mines, Vol. I., p. 4. First Edition.

† Blackstone's Comm., p. 18; Arundel on Mines, p. 3.

‡ Bainbridge on Mines, 4th ed., p. 118; MacSwinney on Mines, p. 27; Rogers on Mines, p. 247.

¶ Bainbridge on Mines, 4th ed., p. 27.

§ William and Mary C., 30; 5 William and Mary C., 6.

substances belonged to the owner of the soil, except in certain localities where immemorial custom had modified the rule.*

At the present time "England has no general mining laws. Legal questions governing the ownership of mines and minerals have been determined on the general principles of the common laws."†

As distinguished from the common law the theory of the civil law is thus clearly stated by H. W. Halleck:—

"All continental publicists who have written upon the subject lay down the fundamental rule, that mines, from their very nature, are not a dependence of the ownership of the soil; that they ought not to become private property in the same sense as the soil is private property; but that they should be held and worked with the understanding that they are by nature public and that they are to be used and regulated in such a way as to conduce most to the general interest of society."‡

C. H. Lindley has presented concisely the theory of our leading mining lawyers as to governmental control after patent, as follows:¶

"The government of the United States does not concern itself with mining lands or the mining industry after it parts with the title. This title vests in the patentee absolutely to the extent of the property granted. No royalties are reserved; nor is any governmental supervision (except perhaps in the isolated case of hydraulic mines in California) attempted. Upon the issuance of the deed of the government the mineral land becomes private property subject to the same rules as other property in the state with reference to the transfer, devolution by descent, and all other incidents of private ownership prescribed by the laws of the state. Briefly stated, property in mines, once vested absolutely in the individual, becomes subject to the same rules of law as other real property within the state."

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* Lindley on Mines, 1st ed., Vol. I., p. 4.

† Lindley on Mines, *loc. cit.*

‡ Introduction to De Fooz on the Law of Mines, p. 10; Lindley on Mines, 1st ed., Vol. I., p. 14.

But lately we are told that the United States "has never waived its right to the precious metals,"* and that "in all states where the Federal Government has never owned the land, and there are 19 such states, the ownership of the precious metals lies with the state government," and "that in states where the ownership of the land has been vested in the Federal government the ownership of the precious metals in like manner, lies with the nation, and that as against the Government no person has a right to gold and silver in any lands in the United States unless this right has been specifically granted to him in the deed of conveyance."†

Here is a most radical difference of theory. Mr. Veatch would have the government resume dominion and control of gold and silver and by implication of other metals beneath the surface of all lands except those in which the minerals were specically conveyed. He thinks the government has the right to grant prospecting permits beneath private property and the power to collect royalties on minerals produced as a result of such explorations. In other words he insists upon it that the United States is in possession of a regalian right but does not know it or has forgotten it. He would have the people wake up and seize what is theirs from all mine operators who are thus wrongfully removing from the ground valuable minerals never specifically granted to them by the government. It can readily be seen that it is a matter of no small moment to ascertain whether such a thing is possible. Here is proposed mining law revision with a vengeance. I have not at hand the figures to show the relative proportion of lands patented as mineral lands and in all other classes; but have no doubt that the lands granted under the homestead, pre-emption, desert land act, private entry, town site, timber and stone, railroad grants and all other laws exceed in the aggregate the lands patented under the mining laws four to one. Now, if the minerals under three-fourths of the privately owned land west of the Mississippi, and practically all the lands east of it, really belong to the government it is high time for the government to assert its right and to exercise some sort of control over its vast pos-

* Bulletin 505 U.S. Geol. Sur., p. 116.
† Bulletin 505, U.S. Geol. Sur., 101.

sessions. This is either a nebulous and iridescent dream or a very important discovery. If the former the bubbles should be punctured, and the mist dispelled, before arousing too many false hopes; if the latter the work of mining law revision at once assumes paramount importance. Fortunately, we have some illuminating opinions of the United States Supreme Court, as a guide and cloud dispeller.

In the case of Deffeback v. Hawke, 115 U.S., p. 400, Mr. Justice Field, after reviewing at length the various acts of Congress relating to the public lands of the United States concludes as follows:—

"It is plain, from this brief statement of the legislation of Congress, that no title from the United States to land known at the time of sale to be valuable for its minerals of gold, silver, cinnabar, or copper, can be obtained under the pre-emption or homestead laws or the townsite laws, or in any other way than as prescribed by the laws specially authorizing the sale of such lands, except in the States of Michigan, Wisconsin, Minnesota, Missouri, Kansas. We say land *known* at the time to be valuable for its minerals, as there are vast tracts of public land in which minerals of various kinds are found, but not in such quantity as to justify expenditures in the effort to extract them. It is not to such lands that the term "mineral" in the sense of the statute is applicable. In the first section of the Act of 1866 no designation is given the character of mineral lands which are free and open to exploration. But in the Act of 1872, which repealed that section and re-enacted one of broader import, it is *valuable* mineral deposits which are declared to be free and open to exploration and purchase. The same term is carried into the Revised Statutes. It is there enacted that lands *valuable* for minerals shall be reserved from the sale except as otherwise expressly directed, and that *valuable mineral* deposits in lands belonging to the United States shall be free and open to exploration and purchase. We may also say lands *known* at the time of their sale to be thus valuable, in order to avoid any possible conclusion against the validity of title which may be issued for other kinds of land, in which years afterward, rich deposits of mineral may be discovered. It is quite possible that lands settled upon as suitable only for agricultural purposes, entered by the settler and patented by the government under the pre-emption laws, may be found, years after patent has been issued, to contain valuable minerals. Indeed, this has often happened. We therefore, use the term *known* to be valuable at the time of sale, to prevent any doubt being cast upon titles to lands afterwards found to be different in their mineral character from what was supposed when the entry of them was made and the patent issued."

And in the case of the Colorado Coal Co. v. the United States, 123 U.S., p. 328, Mr. Justice Matthews uses the following language:—

"A change in the conditions occurring subsequently to the sale, whereby new discoveries are made or by means whereof it may be profitable to work the veins as mines, cannot affect the title as it passed at

the time of the sale. The question must be determined according to the facts in existence at the time of the sale. If upon the premises at the time there were not actual known mines capable of being profitably worked for their product, so as to make the land more valuable for mining than for agriculture, a title to them acquired under the pre-emption Act cannot be successfully assailed.''

Since these are the opinions of the highest court in our land it is probable that although the advocates of radical revision of our mining law may be able to change the form of its superstructure they will hardly be able to mine deep enough to disrupt its solid rock foundations. It will continue to present fundamental differences from the mining law of Canada on the north, and from that of Mexico on the south, but rights already granted will not easily be set aside.

Summarizing these somewhat disjointed remarks, it appears in general that

1. The development and prosperity of all countries are vitally affected by the provisions of their laws relating to mines.

2. Greater inducements and more liberal rewards should be offered in unsettled countries than in districts of denser population.

3. Continuous development work should be required and rigidly enforced, but—

4. No narrow limit should be placed on the amount of property held by an individual or corporation so long as the aggregate amount of work equals the product of the net units of area held multiplied by the amount of development required for each unit area.

5. In case of any contest either between rival claimants or between a locator and the government full privilege should be given of appeal to the courts as in other matters wherein the title to property is involved.

In addition to the above and with particular reference to the United States, taking into account the system of mining law there already established by long years of precedent and custom, the following recommendations are tentatively presented:*

* It should be clearly understood that for these suggestions the writer is alone responsible. They do not in any sense pretend to reflect the views of the Mining and Metallurgical Society of America nor its committee on Mining Law.

a. The apex law should be abolished.

b. Mining claims should be locatable regardless of a "discovery" and held only so long as the specified development work is performed in good faith.

c. Placer locations should be limited to deposits of loose material above solid bed rock.

d. A statute of limitations should establish a reasonable term of years beyond which placer patents shall be immune from attack on the ground of misrepresentation in the patent application.

e. Special statutes should be enacted providing for the location and working of oil, phosphates, rare earths, haloids, and other mineral substances not specifically mentioned in the present laws.

f. Existing titles should be fully recognized and confirmed and no effort should be made to create retroactive legislation.

I have purposely avoided any discussion of the relative advantages or disadvantages of permanent alienation of title as opposed to the government leasing system. For Canada, I am confident the latter system is to be preferred, and am pleased to find myself upon this point in accord with the majority of Canadian mining men.

USE OF GEOLOGY IN IRON ORE EXPLORATION.

By C. K. Leith, Madison, Wis.

(*Annual Meeting, Toronto,* 1912.)

I was asked recently, "Of what use is geology in exploration for iron ore?" My purpose is not so much to make a case for the geologist, as to discuss plans of exploration desirable from a geological standpoint. The regions to which principal reference will be made, for comparative purposes, are Lake Superior, Canada, Cuba, and Brazil.

Exploration of Lake Superior Iron Ores.

Some sort of a geological survey of an area, professional, amateur, or otherwise, is now regarded by all as an essential preliminary to exploration for iron ore. The function of the geological survey for exploration purposes is to eliminate the barren areas. The Lake Superior ores are in certain definite iron formations of sedimentary type which can be followed by ordinary stratigraphic methods, and few now wish to spend money in exploration in an area of granite or quartzite, or other non-iron-bearing rocks. In the past this was not as true as it is now, as shown by the expenditures that have been foolishly made in such areas. So much of the Lake Superior country is drift-covered that the tracing of iron formations requires magnetic surveys and careful study of structure and stratigraphy in order to extend and connect the iron belts properly through covered areas. There is practically no phase of physical geology which can not be employed to advantage in delimiting the limits of the field of most promise for exploration. The geological surveys to date have eliminated all but about 270 square miles of territory in the Lake Superior region from the zone of favourable exploration. In other words, the area of iron formation known and

inferred is about 270 square miles, distributed approximately as follows:

Area of Known Formation.

Michigan	45	square miles.
Minnesota	160	" "
Wisconsin	20	" "
Ontario, adjacent to Lake Superior	45	" "

In addition to the above are many magnetic belts, partly or wholly unexplored, that may add another 100 square miles of iron formation.

The enormous preponderance of the area of Minnesota is due to the Mesabi range, where the beds lie nearly flat, as contrasted with the steeply dipping beds of other districts.

The geological examination still further narrows the field by eliminating from favourable consideration certain extremely magnetic and silicated phases of the iron formation which are known by wide and costly experience to be nearly barren of ore. These parts of the formations may reach from 40 to 45 per cent. of iron in narrow rich seams. They are hard and resistant, and are conspicuous topographically on the erosion surface. For half a century they have attracted the attention of explorers; as soon as one group of explorers have satisfied themselves that there is nothing in this type of formation there is another group ready to go through the same experience. The geologist has shown that this type of formation is a result of igneous or deep-seated metamorphism before the formation had the opportunity to be concentrated to ore; and that this kind of metamorphism has not itself concentrated ore bodies, and, still more important, has put the formation into such condition that the ordinary surface agencies of concentration have later not been able to accomplish any concentration. It is not true that all magnetic portions of the iron formation are to be eliminated because of this, but nearly all of the extremely magnetic and silicated phases are to be eliminated. One of the commonest fallacies is that a strong magnetic belt is a favourable indication of an ore body. Looked at from the standpoint of Lake Superior experience as a whole, a strong magnetic belt is an unfavourable indication for ore close

at hand. In support of this statement I need only cite the slightly magnetic properties of the great hematite bodies of the Mesabi and other Lake Superior ranges, as compared with the highly magnetic properties of the lean east Mesabi, east and west Gogebic, and other parts of the Lake Superior ranges. A strong magnetic belt may indicate the existence of the iron formation and gives a valuable starting point in working toward less metamorphosed phases of the formation where there is better promise of finding commercial grades of ore.

The elimination of the magnetic and silicated phases of the formation means reducing the total area of iron formation in the Lake Superior region roughly by half, leaving about 135 square miles within which to explore. This may be increased in small measure by parts of the unexplored magnetic belts.

It is possible still further to reduce the area for exploration by discarding areas of iron formation which are known to be lean and "tight," that is, areas in which the formation has originally a low percentage of iron and in which the processes of loosening up by weathering essential to the concentration of ore have not been begun. Such areas are recognized in almost any producing district.

By processes of elimination, requiring careful geological study at every step, the explorer may come to a consideration of about 75 square miles of iron formation in the Lake Superior country.

Within the area thus localized the problem now is to find the parts concentrated to iron ore. Concentration is effected by water and the atmosphere, and accessibility of these substances to the iron formations determines the localization of the ores. There is the greatest variety of factors which determine the localization of the concentration—whether the beds are flat or on edge, the existence of impervious basements or covers, faulting, jointing, nature of the folding, porosity, area of exposure to the surface, and other factors. If one stops to think of the variety of ways that surface solutions can get at rocks effectively one must appreciate in some measure the complexity of the conditions under which the ores may be found. Other things being equal, it is apparent that the concentration is roughly propor-

tionate to the area of exposure of the iron formation to the erosion surface, all the remaining factors being subsidiary and modifying. This is something more than the statement of an academic principle, for it has been worked out in terms of acres and tons of iron ore and iron formation for the different districts.

Approximately 80 per cent. of the ore of the Lake Superior iron formations is in the upper Huronian series and this series has produced about 80 per cent. of the total past shipments, and probably has more than this proportion of the remaining reserve.

It is found that, regardless of the modifying factors, a certain percentage of the area of any iron formation may be expected to be ore. In the Mesabi district, after elimination of the non-productive east and west ends of the range, 8 per cent. of the remaining area of the iron formation is known to be ore. In the Vermilion district, between Tower and Gunflint Lake, 2.3 per cent. of the surface of the iron formation is ore. In the Michigan ranges, collectively, the present ore area is .6 of a square mile, or 1.5 per cent. of the favourable iron formation after elimination of obviously barren phases, but making allowance for ore area mined out and probable further discoveries the true percentage is probably nearer 4 per cent. The lower percentages of ore areas in the steeply-tilted iron formation of Lake Superior, as compared with the flat-lying Mesabi does not necessarily mean a smaller proportion of ore, for there are better chances of continuance with depth in the steep-dipping than in flat-lying beds, as I shall show later.

In explorations started on any part of the iron formation which is non-magnetic and non-silicated, from 2 to 8 per cent. of the drill holes, depending on the district, should penetrate ore. The unit of exploration is a 40-acre tract. At least this percentage of the 40-acre tracts, therefore, should show ore. As a matter of fact, particularly in Michigan, a very much larger percentage of the 40-acre tracts, possibly half of them, contain ore. In other words, the small percentage of ore area is distributed widely over the 40-acre tracts on the iron formation.

Careful geological study of any area being explored in detail still further limits the area of exploration. It will be found that

on part of the forty acres the formation is richer than on another part; that it is more leached and porous than on another part, that there are various structural features which favour one part rather than another. Work started miscellaneously over the forty acres will gradually converge toward one spot. The rapidity and effectiveness of this convergence depends largely upon the extent to which the geology, the structural relations and origin of the ores, are understood. I should like to enlarge upon this in more detail. We have attempted in our recent monograph on Lake Superior geology* to tell of some of these conditions. I would here merely emphasize the fact that no rule-of-thumb method or consideration of one or two factors will suffice. There is almost no fact relating to the structure or metamorphism, conditions of sedimentation, chemistry of deposition of the ore, factors entering into secondary concentration—no matter how apparently unrelated to practical exploration—which does not contribute to a comprehension of the possibilities in a given situation, and facilitate the finding of the ore.

After ore is found and the mine opened, intensive geological study is able still further to save much useless work.

In this advanced state of development there are again certain average results to be looked for which should be considered in scaling exploration or mining for the future. The Mesabi ores are easily explored in three dimensions and tonnage estimated. The necessity of inferences beyond ascertained facts is at a minimum. Most of the other ore bodies of Lake Superior show only their edges at the surface and adequate exploration in depth and consequent complete estimates of tonnage can not be expected for many years to come. Some facts assembled by the writer in connection with estimates of ore reserves of Michigan** for the Michigan Tax Commission during the past summer give a reasonable basis for expectation of large tonnage below present workings. In fact, when a depth has been explored comparable to the width of the Mesabi iron formation at the surface, it is not

*Geology of the Lake Superior region, by C. R. Van Hise and C. K. Leith. Mon. 52, U.S. Geol. Survey, 1911.

**Iron ore reserves of Michigan in 1911, by C. K. Leith. Advance chapter from Min. Resources U.S. for 1911, Washington, 1912.

impossible that the tonnage of ore may be as great as on the Mesabi. This depth, however, may be too great for profitable mining, and it may appear further that the percentage of formation altered to ore at depth is not so great as on the erosion surface. The method of forecasting greater depth of ores is as follows:

In order to make a common basis of comparing all ore deposits of varying structure and of different districts, the actual area in square feet was calculated for fully developed bottom levels in ore in each of the Michigan mines. Knowing the total tonnage which has been shipped in the past above this bottom level and adding to it the tonnage in reserve above this bottom level, it is possible to calculate the total cubic dimensions of all the ore now or formerly in the mine above the bottom level. Dividing this cubic figure by the depth of the bottom level, an average *area* is determined for all the levels above the bottom level. This average area compared with the present bottom area gives a fair notion whether the mine is better or worse to-day than in the average of its history. In this method of calculation it appears that the total area of bottom levels of all mines in the Gogebic district with an average depth of 1,456 feet is 20 per cent. larger than the average higher levels mined in the past. In the Iron River district the present bottom levels of all the ore bodies in the district with an average depth of 690 feet, aggregate over twice the area of the average higher levels. In the Crystal Falls district the bottom level at an average of 1,070 feet is about the same as the average levels above. In the Menominee district at an average depth of 1,160 feet, there is a falling off of about 30 per cent. from the higher levels. This is the only case of diminishing area in Michigan, but even this figure promises considerably greater depth to the ores. If the area shows no diminution and the ore bodies show no other signs of ending, it seems to me to follow that there is no fact against an expectation of future as good as the past in an average case.

These figures have to do only with the producing mines of Michigan. There is in addition an area of ore developed by drilling, not yet mined, of 9,000,000 square feet, which, as a matter of fact, is half again as much as the total area of ore in

the bottom level of all active mines. This fact is of interest, as showing how in the oldest part of the Lake Superior iron district exploration is still largely productive of results. I expect it to remain so for some time, not only in areal exploration, but in following ores down when they are found.

All of the foregoing figures are useful as checks or guides in forecasting results from large exploration plans. If the plans are comprehensive enough and are carried out for a long enough period, the results may be expected to approximate these figures.

I cite a concrete illustration of the method of exploration here outlined from a case for which the detailed facts happen to be available to me. From an area of 40,000 acres miscellaneously distributed through Michigan, all was eliminated by geological examination except 5,000 acres. Later, more detailed work on these 5,000 acres cut down the area more favourable for exploration to 3,000 acres. In 50,000 feet of drilling on eight widely-separated properties showing a variety of structural conditions, 46 per cent. of the total footage was in iron formation, the remainder being in rock and surface. Of the total footage of iron formation, 8 per cent. is ore. This figure is to be compared with the percentage of ore area to iron formation area cited above for all of Michigan, namely, approximately 4 per cent. The higher percentage shown by the drilling may be due to luck, or to careful geological work, but I believe it to be due mainly to the fact that a majority of the holes were drilled at an angle with the horizon, to cross-cut the steeply-dipping ore beds. As most of the ore bodies in Michigan are in steeply-tilted rocks, their vertical area is usually larger than the horizontal area, with the result that angle-holes should disclose a little larger percentage of ore than that appearing on the erosion surface. The ore thus found will be opened up and mined. In making up the plans for future exploration and development of the ore body, advantage is being taken of the average facts of depth and persistence of ore bodies in relation to area, which I have described. Ultimate realization may fall short of this average in some properties, but it is likely to run over in others. I shall be surprised to see any wide departure from the average figure.

Of course there is much successful exploration which does not utilize these methods. If the exploration is followed far enough, ore is found in about the average proportions already indicated. If lucky, the explorer may find it at once and not be at the necessity of using these geological inferences. But luck is not likely to be always on the same side in any long campaign of exploration. Where the explorer is limited in the area available to him, or limited in time or funds, his chances are less for approximating the above percentages, but whatever his chances are, they can be utilized to full advantage only by scientific work. In proportion as scientific work is ignored, his average chance, always barring luck, is reduced.

Elementary computation will show that if the explorer on any large plan of operations has a chance of getting ore in 5 per cent. of the area explored, there is an enormous percentage of profit awaiting him. The value of the ore found will, of course, show wide range, depending on its quality, location, and many other facts, but notwithstanding this range the margin of profit makes the plan a reasonably safe one. A large profit is always looked for in mining, but with this large profit there is usually recognized an equally large hazard. The Lake Superior iron district offers one of the few opportunities of which I know for large profit with a hazard so diminished by large-scale scientific operations that it is possible to estimate with reasonable certainty the chances of finding ore. This is the basis for the widespread feeling that iron ore exploration on a small scale is a big gamble, and on a large scale is safe and profitable. There are very few large companies in the Lake Superior region that have followed plans of exploration consistently through a series of years without making a profit. Out of a possible twenty chances in twenty areas they take all twenty and on an average one to two out of the twenty is successful, giving them an ample margin. Certain individuals receiving large incomes from mining properties have found it profitable to set aside yearly portions of their incomes toward exploration, with a fairly definite notion of the percentage of return which could be expected in a long campaign of expenditure of this sort. The increasing use of geological knowledge for such campaigns of exploration may be re-

garded as the growing recognition of the possibilities of eliminating adverse chances by scientific work. If the geologist can eliminate only one or two of the twenty chances to be taken, more than the cost of his services is saved.

But, the question may be asked, how about actual discoveries made by geologists as compared with other explorers? As there is only one geologist to a hundred or more explorers, it is, of course, true that the geologist has not found as much ore as the latter, although I might cite cases of conspicuous success on the part of geologists. The real question, however, is not whether the geologist has or has not found most of the ore, but whether the use of geological knowledge has eliminated adverse chances to a sufficient extent to show a margin for operations conducted by him over those of equal number conducted in less scientific fashion. I believe there would be no essential disagreement in answer to this question. Now that the ore bodies have been found which outcrop or are otherwise easily accessible, geological inference is even more necessary than in the past, and we are likely to see an increasing use of this information.

The further thought may arise that it may be unnecessary to repeat this formidable programme of geological work for every piece of exploration. It is true it is not. The geologist has mapped the territory and set certain guide lines which can be ascertained in a few minutes by inspection of published maps. He has set the guide lines for understanding of structural relations and the origin of the ore. This is so much gained in taking up any plan of exploration, but there are few areas in which it is not necessary to know more about the distribution, structural relations, and origin of the ores, to arrive at a sufficiently close basis for exploration. A general knowledge will help, but it leaves a wide margin for random and unnecessary expenditure. Even if the published information in any area is reasonably complete the interpretation of this information and its application to a specific property are not always safely made by a non-technical man, and there is still room for the geologist with an understanding of a wide range of geological conditions to add a certain margin of safety and effectiveness to the explorations.

Explorations of Canadian Iron Ores.

Geological conditions similar to those of the Lake Superior region are repeated rather generally through Ontario and elsewhere in Canada. The general plan of using geology to concentrate explorations outlined for the Lake Superior region holds, so far as I know, for Canada. It may be of interest to take stock of the present progress of exploration for iron ore in Canada to see how far this plan has been followed, what remains to be done, and how definitely expectations can be stated. In locating and mapping the known iron belts the first step in elimination of nonproductive formations is being rapidly taken, though much remains to be done in the vast unexplored tracts of Canada. The elimination of lean magnetic portions of the formations has been much less effectively done. I believe that there has been some lack of recognition of this adverse factor. So far as I know the situation, at least a half, perhaps more, of the iron belts so far discovered in Ontario must be eliminated for this reason. Of the remainder somewhat more can be eliminated because of leanness and obvious lack of any effects of agencies of secondary concentration. There remains, however, a substantial residuum of iron formation in which there are reasonable chances for finding ore. Close structural studies have been made in but few places.

May the chances for ore be reduced to the percentage basis? Underground exploration has thus far been carried on to so small an extent that the ratio of ore to iron formation has not been established. We are compelled, then, to rely on analogy with similar formation in the Lake Superior region. It may prove that the chances of ore within the favourable iron formations approximate those of the Lake Superior region, namely, that ore occupies 5 per cent. of the area, but there is an adverse factor that in my judgment materially reduces this chance. The high average percentages of ore to iron formation of the Lake Superior country are based mainly on ores of the Huronian, which constitute over 90 per cent. of the Lake Superior ores. Iron formations of Huronian age thus far found in Ontario constitute only a small percentage of the total. They are principally of Keewatin age, which in the Lake Superior region contain less

than 10 per cent. of the ore, and in which the percentage of area of ore to iron formation has been found by actual measurement to be 2.35 per cent. This comparison seems to me to throw light on the slow discovery of high-grade Canadian iron ores, as compared with expectations based on the large areas of Canadian iron formations and their assumed similarity to average Lake Superior iron formations.

Eight or ten years ago I began explorations for ore in Canada on a somewhat comprehensive scale, with the expectation of approximating the Lake Superior percentages by covering a wide enough area of iron formation. Recognition of the geological fact of the Keewatin age of the Canadian iron formations now seems to me to reduce this chance fully to that of the Keewatin iron formations of the Lake Superior region—in other words, to make the chances about half as favourable as in the Lake Superior region on an average. I do not imply that large quantities of ore will not be found in Canada. I think they will. I am merely trying to formulate some basis of quantitative comparison with Lake Superior in order to determine what may be a reasonable expectation from any large-scale plan of exploration of Canadian ores.

The careful detailed geological studies of small areas accompanying underground drilling remain largely to be done. When it is accomplished I anticipate results approximating the above figures.

EXPLORATION OF CUBAN IRON ORES.

I here refer to the great new reserve of medium and low-grade ores occupying so much of the area of central and northeastern Cuba, and not to the ore of quite different type which has been mined for many years in the Santiago district. The ores of northeastern Cuba are of such enormous quantity that they are likely to play no inconspicuous part in the world's future iron trade.

The use of geology on the northeastern Cuban ores may seem somewhat redundant, in view of the fact that so much of the ore is exposed at the surface without even a covering of grass. As a matter of fact, however, the ore was first carefully

examined and brought to the attention of the public by the geologists attached to Gen. Wood's staff during the first American intervention. Much more recently the geological engineers of the large companies have played a large part in the location and delimitation of these fields.

The essential geologic fact is that the ores are surface alterations of serpentine rocks. It follows that the distribution of the serpentines must be ascertained. The fact that they are igneous rather than sedimentary rocks determines certain features of their distribution.

Within the serpentine areas the ores are localized by certain physiographic conditions. On the central plateau where the drainage is sluggish the ores may be fairly thick. At the edges of the plateau where erosion is active the ores have been nearly or quite removed. Where erosion has followed concentration slowly, the ores remain; where it has followed more rapidly, the ore is thinner or lacking. The problem then becomes one of conditions and speed of erosion—a physiographic problem—contrasting in essential respects with the Lake Superior problems. The recognition of this relation of the ores to erosion surface by a local geological engineer made it possible to forecast the discovery of ore across a mountain chain in a difficultly accessible interior and led to one of the most recent large discoveries of ore.

Much remains to be done in correlating the ores and physiography. Other geological problems are: the reason for the locally increased depth of alteration of the serpentine to ore, the effect of climate and vegetation on the superficial enrichment and texture of the ore, and the interpretation of certain conglomerates in the ore of the Camaguey district to ascertain what part of the ore may represent concentration from an overlying limestone on the serpentine in addition to the concentration of the serpentine itself.

The chemical processes of concentration of the Cuban ores varies in no essential respect from those which have made the Lake Superior ores. The difference is that the concentration originated from serpentine rather than from iron formation and acted on all the area of the serpentine instead of being localized

in small areas by complex structures, as it has in the iron formations of Lake Superior.

EXPLORATION OF BRAZILIAN IRON ORES.

There has been discovered in east-central Brazil, about 300 miles from the coast, an iron ore field more nearly resembling that of Lake Superior than anything before discovered, in grade, quantity of ore, area, geology, in probable pre-Cambrian age of the ores, and in sedimentary type of the ores. Here has been a fine opportunity to apply the geological principles developed in the Lake Superior region. The Brazilian field is not glaciated and much of the ore appears at the surface, but much of the field is covered with erosion detritus, more or less cemented, which conceals the geology, especially in the valleys, as effectively as does the drift in the Lake Superior region. There is the same necessity for careful stratigraphic and structural work in limiting the iron formations and inferring their extensions and connections. With such work it has been a comparatively simple matter to locate important ore bodies, which, if left to random exploration, might not have been discovered for many years.

A study of the origin of the ores discloses a fact of utmost significance in exploration, namely, that the rich ores are not local pocket concentrations in a great area of iron formation, but are, in fact, original iron formation sediments deposited in their present highly concentrated condition. In exploration it is not necessary to hunt for the local structural conditions favouring secondary concentration. The requisite is to follow out the entire bed, as one would follow a bed of quartzite. Somewhat the same uniformity and continuity and ultimate tapering out are to be expected both along strike and dip as would be found in a quartzite bed. I need not dwell on the enormous importance of this fact in the exploration for ore and especially in the estimation of tonnage.

There are, in this Brazilian field, additional but lower grade ores which clearly result from secondary concentration, and are analogous in every respect to those of Lake Superior. It is entirely possible that important deposits of this type will still be found, as the places favourable to their concentration are likely

to be under valleys or slopes, which are now covered with detritus, requiring underground exploration.

The Brazilian field is one of the few fields where by far the greater part of the tonnage—known to be at least as great as at Lake Superior—has been located and estimated largely by geological inference prior to commercial development.

CONCLUSION.

Having complimented the geologist under guise of describing exploration methods, it is now appropriate to admit that mining men have prospered well in the past and that some of them are now prospering, without the aid of geologists. I have a lively respect for the knowledge of mining men on geological facts in territory with which they are familiar. But as exploration is primarily a geological problem, it follows that the geologist should have a primary part in the work. The mining man manages a vast variety of interests, often with marvellous success, but as an enterprise grows in size and complexity, specialization becomes necessary. In many cases specialists are placed in charge of the mechanical and civil engineering and railway operations long before it is thought necessary to place exploration in the hands of a geologist. So far as I have any argument to make in this paper (rather than casual comment on existing conditions) it is for recognition of the fact that exploration is mainly a geological problem and that exploration falls short of maximum effectiveness in proportion as it fails to use geological inferences.

In closing, I would say just a word about the reaction of mining and other commercial conditions upon geology itself. Brooks* has shown that in 1890 only 12 per cent. of the publications of the U. S. Geological Survey related to applied geology, while in 1909 this percentage had risen to forty-seven. There is no reason why applied geology should not be of the highest scientific type, but, as a matter of fact, much of it is not geology at all. To quote from Brooks: "There is, however, grave danger that, carried away by the present furore for practical results, we may lose sight of

*Applied Geology, by Alfred H. Brooks. Jour. Wash. Acad. Sci., vol. 2, No. 2, Jan. 19, 1912.

our scientific ideals. Applied geology can only maintain its present high position of usefulness by continuing the researches which advance the knowledge of basic principles. Future progress in applied geology depends on progress in pure geology.'' In the particular field I have here discussed it can not be too strongly emphasized that the scientific principles are the real basis of the aid to mining and exploration, and that too much time spent by the geologist in the application of principles rather than in development of principles must ultimately retard the work. After all, the applications can be made to a large extent by the mining man or mining engineer. The understanding and development of the fundamental principles can be accomplished only by the geologist. I would plead that the geologist be allowed the fullest freedom in this direction, merely as a commercial consideration, and that he should not be confined, nor his work judged alone by the direct practical results.

THE PERPETUATION OF SUCCESSFUL MINING COMPANIES.

By R. B. Lamb, Toronto, Ont.

Under this title it is desired to suggest that in the interests of economy and efficiency, the development of the metal mining industries should be undertaken in greater measure by corporations already established and adequately financed. In other words, such companies not content with the success attending the operation of one mine should acquire new properties or interests in properties which they might control and work. Thus would they perpetuate themselves, with advantage to the industry and themselves. The organization expenses and business management of small undertakings are frequently disproportionately heavy; often the capital is insufficient to admit of the employment of a competent engineer to direct operations. These are necessarily handicaps; they may even be the direct cause of the non-success of a venture. The acquisition of such a property by an established corporation eliminates the item of organization expense and the waste attending the operation of securing capital for a new undertaking. The large corporation, amply provided with funds, can transfer its staff from one place to another at need, can command the services of highly qualified technical men, and in other directions is in a better position than either individuals or small joint stock companies to successfully undertake the development and operation of a mine. In respect to the acquisition of mining property, the established corporation has also special advantages and opportunities. It can invariably buy cheaper or obtain better terms from the owner than can the individual purchaser or promoter whose ability to meet payments as they fall due may be a subject to doubt or uncertainty.

Meanwhile, the terms on which prospects should be acquired should be based on the principle of the working option rather

than that of immediate cash payment. This in time will become the general rule. It is highly important in Canada especially that the prospector or claim-owner should recognize the fairness of an arrangement whereby he shares with the purchaser the risk envolved. When, as is often now the case, an unduly high price is paid for a prospect, its subsequent profitable operation is not possible. Some of the well-known Cobalt mines afforded exceptions to this rule. It nevertheless holds good in the main; and it is significant that Cobalt mining companies, now endeavouring to perpetuate themselves by acquiring other property, do not offer to make cash payments until they have been given the opportunity of proving values.

Large profit-earning corporations may very readily acquire new properties without interfering with their main operations; while corporations whose profits are small should make such acquisitions in order to provide for their continued existence.

It is not essential that the corporation should acquire the exclusive interest in a mine; it should, however, hold the control and thus have absolute direction of operations. The continuation of the existence of any wealthy, properly organized mining company postulates, of course, an industrial basis; and it is now generally recognized that the larger the modern organization (often developed from a small beginning) the more effectively, economically and safely can it be conducted. The power of co-operation between the various branches of any industry becomes more pronounced as the industrial unit becomes larger. Capital provides the power, qualified management is the force that directs it. Under the direction of experienced corporations mining enterprise is placed on a footing more nearly approaching that of industrial undertakings generally regarded as stable.

The Mines Company of America is a well-known example of what may be accomplished on the lines here suggested.

ACCIDENT PREVENTION AND MUSEUMS OF SAFETY.*

By W. H. Tolman, Ph.D.†

Safety engineering is the outcome of the principle that safety and health are fundamental to efficiency. It has been demonstrated, both in the United States and in Germany, that fifty per cent. of accidents in industries are preventable; and this very radical reduction has been accomplished by a regular educational campaign conducted by museums of safety. In Germany the principles taught are even inculcated in the minds of children at the elementary schools, while those of maturer years are instructed by the means of popular lectures and the distribution of easily comprehended pamphlets. The Berlin Museum was opened in 1903, the government providing the site and building and contributing as well an annual appropriation for its maintenance. The German government was so impressed with the utility of the work accomplished that four years later this museum was enlarged and a second museum, including a laboratory for perfecting safety devices, was established at Munich. Here safety devices, when their practicability has been proved, are displayed as full sized models. Museums of Safety on similar lines are now established in numerous important centres throughout Europe.

The American Museum of Safety.

The American Museum of Safety, the twelfth institution of its kind in the world and the first in the United States, had its inception in two special expositions of safety in New York City —the first, in 1907, lasting two weeks, and the second, in 1908, lasting two months.

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*Abstract of a lecture delivered at the Annual Meeting of the Institute, Toronto, March 4th, 1912.

†Director of the American Museum of Safety, New York.

These beginnings led to the formal organization of the American Museum of Safety, which now holds a special charter of incorporation granted by the Assembly and Senate of the State of New York. The present headquarters of the Museum are in the United Engineering Societies' Building, 29 West 39th Street, New York, where it has on exhibition all kinds of devices for safeguarding the lives, limbs and health of those engaged in industrial pursuits. These quarters are already outgrown, and more space is needed for the display of additional valuable exhibits and to meet the increasing demands made upon the museum for detailed information.

According to the Museum's special charter—Chap. 152 of the Laws of 1911, State of New York:—

"The objects of the corporation hereby created are to study and promote means and methods of safety and sanitation and the application thereof to any and all public or private occupations whatsoever, and of advancing knowledge of kindred subjects; and to that end to establish and maintain a museum, library and laboratories, and their branches, wherein all matters, methods and means for improving the general condition of the people as to their safety and health may be studied, tested and promoted, with a view to lessening the number of casualties and avoiding the causes of physical suffering and of premature death; and to disseminate the results of such study, researches and tests by lectures, exhibitions and publications."

The American Museum of Safety is absolutely non-commercial. No orders are taken, no exhibits are sold, and no charge is made for space. Many of the devices are not patented, but are practical, home-made appliances, though efficient. No exhibits are accepted unless they have decided safety features, and until they have passed the Museum's Board of Approval, whose personnel is made up of experts in the various industries. Demonstrations are made by the Museum's own staff. The Museum is free to the public and open every day—excepting Sundays and holidays—between the hours of 9 and 5.

The Museum's activities are centered in three great departments—Accident prevention, industrial hygiene and mutuality.

In the first of these, attention is given to questions of safety and to collecting and exhibiting simple, practical safeguards for dangerous machines and processes, drawings and photographs, and by means of actual devices and models. The most highly specialized collection is contained in the Iron and Steel Section, under the chairmanship of Mr. Charles Kirchhoff. Here may be found all sorts of safety devices in actual use in the iron and steel and allied industries: safeguards for blast furnaces, open hearth, bessemer, blooming, rail, skelp, slabbing, galvanizing, pipe and wire mills; power stations, yards, shops, elecricity and transportation.

These collections are of particular value to engineers, factory inspectors and foremen, who come to the Museum to study them and to make drawings and tracings for the installation of similar devices in their own plants.

The superintendent of a plant employing about 6,500 men sent a special committee an a three weeks' tour of investigation of safety devices and methods in western mills and plants. His representative, coming to the Museum, remarked: "I learned more of simple, practical safety devices in my first visit to the Museum than I obtained from the collective experience of the three weeks' tour of our inspection committee."

One day a man walked in with a bulky package done up in canvas. "I got your letter," he said, "and came as quickly as I could." We found that he was too poor to express his model, but he was determined to be present and explain how his elevator cage worked. The next day a mining superintendent from Western Pennsylvania, who had been detailed by the president of his company to study the Museum, was instantly attracted by this model, saying, after a thorough examination, "That one model has more than repaid me for the money and time spent in coming here."

In its Department of Sanitation, the Museum aims to show how factories, mills, workshops and homes may be made sanitary; and especially how to lessen the ravages of occupational diseases. The Department of Mutuality concerns itself with means for promoting the efficiency, comfort and happiness of

wage-earners and for bringing about a better understanding and mutuality of interest between employers and employees.

In addition to the specialized collections of devices, models, drawings and photographs which may be studied at the Museum's rooms, the educational work has been extended by means of free illustrated lectures, at selected centres of industrial and commercial importance. The Iron and Steel Section alone has conducted an educational campaign at mills and plants, where superintendents, works managers, engineers and foremen have assembled to learn what has been accomplished through the introduction of safety devices in their industry. These audiences have ranged from 300 to 2,100 men, and all have been greatly impressed with the simple, practical character of the safeguards described.

By special arrangement, evening lectures have been given at the Museum, before the New York Commissioner of Labour and the State Factory Inspectors, the DuPont Powder Works' superintendents, the New York section of the Institute of Mining Engineers, the National Electric Light Association, the Midvale Steel Company's superintendents and foremen, the Society of Hungarian Engineers, the Society of Heating and Ventilating Engineers, the American Electric Railway Association, the Safety Committee of the United States Steel Corporation, and similar bodies.

Another very important branch of the Museum's work is the organization of Safety Committees in shops and works, and in furnishing the practical information necessary in carrying on the work of accident prevention. For example, the Rochester Railway and Light Company, following the suggestions of the Museum, appointed a Committee of Safety, which, in turn, has appointed eight sub-committees to deal with the problems arising in the various departments. A member of a large dry goods firm in the Middle West, after listening to the Museum lecture and before leaving the hall in which it was presented, formed a Committee of Safety for the establishment, consisting of the electrician, the engineer and himself.

With a view to stimulating the invention and introduction of safety devices in all the industries, and the promotion of

hygiene and sanitation, four gold medals are annually awarded by the American Museum of Safety.

The Scientific American Medal of the American Museum of Safety is presented to such individual or corporation as has produced and exhibited in the Museum, within a recent period of years, any practical device which, in the judgment of the Jury of Awards, best conserves human life and limb in the processes of industry.

The Travelers' Insurance Company's Medal of the American Museum of Safety is awarded to the American employer, or corporation which, in the judgment of the Jury of Awards, has in a recent period of years, achieved greatly in the conservation of the lives and limbs of its work-people, by means of safety devices for machines and processes.

The Louis Livingston Seaman Medal of the American Museum of Safety is awarded for process and achievement in the promotion of hygiene and sanitation and the mitigation of the evils of occupational diseases.

The Emil Rathenau medal has been placed at the disposal of the American Museum of Safety by the Allgemeine Electricitæts Gessellschaft, Berlin, to be awarded annually for the best device or process in the electrical industry for safeguarding industrial life and health.

The American Museum of Safety is the only organized effort in the United States for safety in industry and for bringing a knowledge of safety devices and their practical application, to employers, workers and the general public, through its collections, its manuals and leaflets of safety, its special report service and its illustrated lectures.

It is impossible to estimate the far-reaching influence of such an institution, which, to accomplish its widest usefulness, should be housed in its own building with adequate resources for maintaining its great work This is the present aim of the Museum, one in which every public-spirited man and woman in the United States should gladly co-operate.

The American Museum of Safety is absolutely non-commercial and non-political. The Metropolitan Museum of Art and

the Museum of National History offer desirable examples, the State providing the buildings, the city giving the land, and private subscriptions providing the current expenses. In respect of the Museums of Safety in Amsterdam and Paris, the same provisions obtain.

The American Museum of Safety is the pioneer institution of its kind in this country. The Board of Trustees is constituted of men possessing public spirit, and professional and technical ability, who devote their services gratuitously to the promotion of the work of the museum, which is that of the conservation of human life.

Meanwhile the movement is extending rapidly; for in Europe fourteen museums have now been established.

The Berlin Museum of Safety—probably the best equipped of the European museums—has 64,000 square feet of space for exhibiting purposes. Wherever possible, the machines are of full size and are power driven, so as to show the safety devices in actual operation; otherwise, the application of the safety devices is shown by means of models, drawings and photographs. In the courtyard of the Museum, safety scaffolding, ladders and other appliances for use in the building trades are demonstrated. Within are found various exhaust systems for dust, smoke and vapours; exhibits showing the nutrition of various foodstuffs; workmen's dwellings, systems of ventilation, heating—in fact, everything concerning the protection of the workman while at his work or at home.

The Dresden Museum of Safety and Industrial Hygiene is the outgrowth of the great international exposition on these subjects, which was held last year in that city, and which, during the six months it was open, was visited by more than 5,000,000 people.

In Germany the Museums of Safety are supported entirely by the Government, which believes that "every life saved is a national asset."

The Amsterdam Museum of Safety, opened in 1893, illustrates ideal co-operation, which could be followed to advantage in our own country. The city has given the land, the State the building, and private contributions provide for the maintenance.

The Paris Museum of Safety is housed in the National Conservatory of Arts and Trade, and already has outgrown its headquarters. The other ten European Museums are to be found in Munich, Vienna, Milan, Moscow, Zurich, Stockholm, Copenhagen, Helsingfors, Budapest and Gratz.

The several departments of and the purposes served by these museums are enumerated in the following list:—

1. A department of safety devices, where practical, simple, safeguards for the protection of dangerous machines and processes may be shown and interpreted, by means of actual machines, models, photographs and drawings.

2. A department of sanitation, to show how factory, mill and workshop may be made sanitary, and the best methods of preventing occupational diseases and poisons.

3. A laboratory for the perfection of safety devices and processes.

4. A department of inspection, through which expert advice is given to and on any point concerning provisions of safety.

5. A reference library, containing works on accident prevention and industrial hygiene, as well as photographs, special reports, documents and other literature.

6. Photographs of safety devices, with descriptive text, to be sent to managers, superintendents, shop foremen and others, in order to show them specimens from which they may select the ones best suited to their needs. This department also lends sets of photographs, with text, to technical schools, colleges and other educational institutions.

7. Free illustrated lectures, covering the important points of safety and sanitation, at selected centres of commercial and industrial importance.

8. The organization of Committees of Safety in industry, and in furnishing such technical information as they may be needed.

Provisions in Mines.

In mines, science and skill may do much to promote the safety of workmen, and in this connection it may be of interest

to instance the precautionary measures adopted at one of the mines of the H. C. Frick Coke Company:

The fans are of exceptional power. So far as practicable, the galleries and workings are supported by concrete and steel. The lifts are protected by automatic gates. Notices are prominently displayed indicating the direction of exits. Disused workings are closed. Electricity is employed for shot-firing. An ingenious device is in use for derailing runaway cars. In addition to the usual practice of testing safety lamps, a second test may be made at the pit bottom and the miner searched for matches. In the stables is a safety device to prevent men from injury from the mules; and iron trucks with metal covers are used to convey fodder to the mine stables. The walls of the galleries are washed to remove dust; and directly gas is detected in any part of the mine, the section is abandoned until the air is again pure. The men are drilled in methods of first aid to the injured, and the Draeger apparatus is in use. Rules in various languages are posted in conspicuous places. The first of these rules is:

"Strict compliance with the mining laws of the State of Pennsylvania shall be the first duty of each and every employee, at all times and in all circumstances; and *safety* must be the first consideration of superintendents, mine foremen and all others exercising authority, or charged with the direction of operations in every department; quality of product, second; and cost of production, third."

DISCUSSION.

MR. G. G. S. LINDSEY:—Anything that has to do with conserving human life in connection with mining is exceedingly important. We all like to pat ourselves a little bit on the back and that picture of the effect of modified stimulants that I saw so graphically portrayed on the screen by the lecturer, reminded me of an incident the relation of which may be of interest. I once had occasion to receive a deputation of about 600 workmen of a particular mine who desired permission to rent a piece of

land for the purpose of building a clubhouse. I knew in advance the object of this visit, and I was ready with my answer. I told them they could not rent a piece of land, but I would be delighted to give them a piece of land and I would build them a clubhouse; but on one condition, namely: that they would sell beer to members. That was a thing they wanted but did not ask, because they never expected to obtain the privilege even in their own clubhouse when built. The mine town at which the men lived, was owned exclusively by the company, was a "closed town" and was five miles away from an "open town" on the main line of railway, and when the men went down to the open town they would get very drunk, and after Sundays (as was shown on the screen) the number who did not turn up for work was greater than it was on the days that were not Sunday, and after pay days the lay-off occupied the whole breadth of the screen. So I was delighted to have a chance to say to these men, what was in effect that if they would give up going to the town on the railway and would stay at home they would get all the beer they could drink at cheap prices. They were paying in town 25 cents for two glasses of beer, and another condition I made was they should sell 5 glasses of beer for 25 cents. They ultimately sold six for 25 cents. After things were well under way, instead of having a very large number of the men "lay off" for two, and sometimes three days after pay day, which came once a month, not 30 per cent. lay off." The mild stimulant beer took the place of the strong stimulants whiskey and spirits of the town, in the absence of the use of which the men returned to their work after pay day in very much larger numbers than formerly. So I am entirely in accord with Dr. Tolman that there is nothing so useful as to encourage the use of mild stimulants among working men.

Dr. Tolman's platform of mutuality has two planks, and I suggest that he should develop the second plank of that platform a little more. While it is incumbent on the employer to do everything he can to preserve the life of the workman there is the corresponding duty on the part of the workman to do all that lies in his power to see that accidents do not happen in the proportion in which they do in mines, because very often they

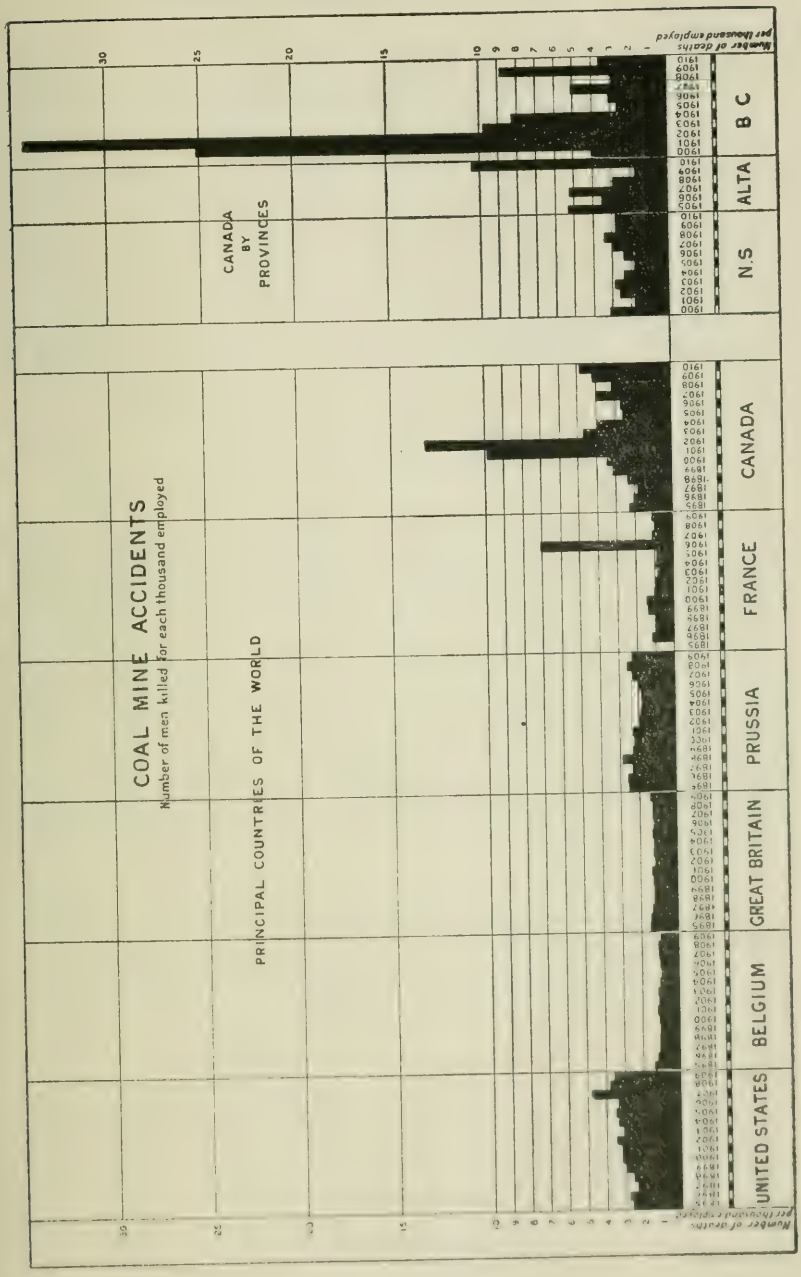
are due entirely to the carelessness of the men themselves. I think this valuable lecture might be expanded on the latter point. If the distinguished lecturer would say a little more along the line of obligation of the workman to take care of his life in the interests of the employer, of himself, and of the community, it would add interest, for this makes for mutual good as much so as the performance of the duty of the employer to take care of the lives of the workmen in the interests of both.

MR. THEODORE DWIGHT:—A rather interesting case occurred about ten years ago at the coal mines of Tesla, California. R. H. Norton was manager. The company had a good deal of trouble from drunkenness; the men patronized a saloon on the company's property. Mr. Norton had the power in his own hands by reason of the ownership of the ground by the company. He drove out the saloonkeeper, organized a saloon on the company's account, offered the men good liquor at a low price, and all they wanted, making only the one condition that if any man became disorderly the saloon was to be closed for three days. The result was that if a man began to indulge too freely he was promptly kicked out of the place by his comrades, who did not want the place closed for three days. The plan worked very well, and excessive drinking ceased.

MR. W. J. DICK:—Dr. Tolman has shown what has been done in Germany and the United States in order to reduce the loss of life caused by accidents in industrial work.

I have prepared a chart (plate) showing the death rates, per thousand men employed, in the principal coal-mining countries of the world. A study of this chart will show the necessity of adopting additional means in order to lessen the number of fatal accidents in the coal mines of Canada.

In coal mining the safety of the mine depends, to a large extent, on the individual intelligence of every man employed in


COAL MINE ACCIDENTS
Number of men killed for each thousand employed
PRINCIPAL COUNTRIES OF THE WORLD
CANADA BY PROVINCES
UNITED STATES
BELGIUM
GREAT BRITAIN
PRUSSIA
FRANCE
CANADA
N.S
ALTA
B C
Number of deaths per thousand employed

the mine. Fire bosses and shot-firers are appointed by the management to examine into the state of ventilation and supervise the firing of shots, but it is impossible to guard against the acts of individuals, brought about by carelessness or ignorance.

In order to give all the minor officials, and, at least, a percentage of the ordinary employees, the opportunity of obtaining a better technical training, it seems necessary for the provinces to adopt a system of technical education for miners. I understand that Nova Scotia has already done much in this direction.

MR. G. G. S. LINDSEY:—Is the chart based upon the tonnage of coal?

MR. W. J. DICK:—The chart is based on the death rate per thousand men employed. It is impossible to compare the death rates in the different countries of the world from a tonnage basis on account of the difference of conditions in Europe as contrasted with Canada or United States. In European countries coal mining has become a very specialized science, and the mining of coal is done by a class of men whose fathers and grandfathers were miners before them. While this is true the following table shows that the conditions in the mines of Canada and the United States are such as to favour a larger production per capita:

MR. G. G. S. LINDSEY:—You have picked out the worst year in all British Columbia's history; the year of its worst calamity. If you arranged the figures over ten years, that very projecting steeple on the chart which represents British Columbia would have to be cut down to the level of the United States.

MR. W. J. DICK:—I am not making special reference to any particular year in British Columbia's history or the history of any other province for that matter, but am endeavouring to show the need of reducing the number of fatal accidents in Canada. The chart shows the death rate, by provinces, in the coal mines of Canada from 1900 to 1910, inclusive.

Table showing average annual output of coal per man, above and below ground (in metric tons) in the principal coal mining countries of the world:—

Country.	1906.	1907.	1908.	1909.	1910.		
*Great Britain	281	284	269	264	255	metric	tons
France	192	200	192	199	...	"	"
Germany	340	337	323	316	...	"	"
Belgium	169	166	161	164	...	"	"
United States	586	644	546	627	626	"	"
Canada	442	429	424	390	468	"	"
Canada by Provinces:—							
British Columbia	410	354	347	368	385	"	"
Nova Scotia	465	475	465	428	530	"	"
Alberta	404	401	404	348	451	"	"

*Does not include fire clay or iron stone got from coal mines.

INDUSTRIAL EDUCATION FOR MINERS.

By Frederick H. Sexton, Halifax, N.S.

(*Annual Meeting, Toronto,* 1912.)

By industrial education for miners, I mean the special technical education adapted to the men who cut, load, and otherwise handle the coal or ore in and about a mine, as distinguished from the college training of youths for the profession of mining engineering. This country and the United States have generously provided for the latter, but have shamefully neglected the former educational field. On the continent of North America, practically no facilities have been provided at the public expense for the education of men and boys employed as wage-earners in the mining industry.

Stringent laws have been enacted in those states and provinces where coal mining is prosecuted to any great extent, requiring mine officials to possess certificates of competency based upon examinations in the scientific and technical subjects upon which the science and art of coal mining are based. The governments which passed these laws have cheerfully furnished august examining boards for the granting of such certificates. The ambitious miner, however, who desired to rise to a position of higher responsibility, was compelled to acquire the knowledge necessary to qualify himself, by means of private study or by an expensive and laborious correspondence course. A small number of philanthropic institutions and some universities which received state (or provincial) and federal grants have made some attempts to cope with this great problem, but they have never accomplished more than a tittle of the diffusion of technical knowledge which this educational need demands.

The correspondence school has been the most efficient agent in this country in the preparation of miners for examina-

tions. It is interesting to note that the greatest of these schools started its phenomenal career in its efforts to supply technical instruction by mail to the miners in the anthracite district of Pennsylvania. When one considers, however, the great inherent practical difficulties of correspondence instruction, especially in regard to the vast sums of money spent in this direction in comparison with the comparatively small number of pupils enrolled who actually complete the courses, one can hardly say that the correspondence schools provide adequate means for secondary mining instruction in America. The huge enrolment points rather to the large need to be fulfilled in some more efficient manner.

Prof. H. H. Stoek, in a paper read before the Institute a few years ago, clearly outlined the efforts which had been made in Canada and the United States in regard to secondary mining education. He mentioned the mining school at Freeland, Pa., which was founded so many years ago by that eminent engineer, Mr. E. B. Coxe, and which is now maintained by his heirs. The school is still doing excellent work, and the wonder is that this useful institution has not been duplicated in other coal mining communities, especially since the consolidation of the anthracite business into the hands of a few powerful corporations. The whole question of industrial education for miners receives so little attention in the United States, however, that this efficient, though modest effort is not even mentioned in a voluminous and otherwise comprehensive report on "Technical Education in the United States," issued by the U. S. Department of Labour in 1911.

The State Mining School in Plattsville, Wis., situated in the centre of the lead mining district of that state, is working out its problems and is becoming a more efficient factor every year in the preparation of foremen, superintendents, and managers for the local metal mines.

The State Y. M. C. A. of Pennsylvania is rapidly progressing in the establishment of its mining institutes and mining schools in both the anthracite and bituminous districts of that State. The movement is receiving increasing support from the mine operators. The Association labours under some seri-

ous disadvantages. It must lay much stress on the social side of the work, and is compelled to depend on students' fees and voluntary subscriptions for financial support.

Prof. Stoek also outlined the splendid work of the Kingston School of Mines and the University of Toronto in the summer courses for prospectors in Ontario. The members of the Canadian Mining Institute are familiar with this work and with its far-reaching practical results, so that no further mention of it is necessary here.

If we would know our duties more fully in the direction of special industrial education for miners, we must examine the institutions maintained for this purpose in foreign countries. We have by no means as much to learn in the sphere of college training of professional mining engineers as we have in the equally important sphere of technical education of a secondary nature. Hence the following summary of the facilities for the education of miners in the leading countries in Europe should be of interest:—

SECONDARY MINING EDUCATION IN GREAT BRITAIN.

In England and Scotland, secondary technical education for miners is offered for the most part in well organized evening schools. Nearly every mining community has its special technical classes in mining. The county is the common unit of organization. The attendance in coal mining districts is necessarily greater than in metal mining districts, because of the strict regulations requiring certificates of competency for officials in coal mines. The examinations furnish the incentive to study.

All the coal mining schools in Great Britain resemble each other very closely. The full course covers five or six years and requires the attendance of the students two or three evenings a week for about six months of each year. Some of the classes in the last two or three years are given at a central college or university on Saturday afternoons. The larger the mining population in any town, the more extensive are the mining classes offered. Small fees are almost always required, but everywhere there are such a large number of scholarships that no ambitious man is prevented from attending the full course on account of poverty. In many districts the students in outlying

towns have all their travelling expenses paid when they attend classes at a central college. These technical classes in mining are supported almost entirely at public expense. The cost is shared by the community, the county, and the Imperial treasury.

The organized course offered in the county of Lanarkshire, Scotland, under the direction of the Glasgow Technical College is given here as representative of what exists in the form of technical education for miners in Great Britain.

Glasgow Technical College.—Syllabus of Instruction.

Session—About 25 weeks each year.

First Year (Preparatory).

Arithmetic	6 hours per week.
Algebra	
Geometry	
Elementary Physics	
Geometrical Drawing and Sketching	

Second Year.

Arithmetic	1 hour per week.
Algebra	
Mensuration	
Geometry	
Geometrical Drawing	2 hours per week
Technical Mechanical Drawing	
Coal Mining	1 hour per week.

Third Year.

Arithmetic	1 hour per week.
Algebra	
Mensuration	
Geometry	
Trigonometry	
General Science	2 hours per week
Coal Mining	1 hour per week.

Fourth Year.

Coal Mining Mechanics	1 hour per week.
Steam Machinery	2 hours per week.
Mining Laboratory	2 hours per week
Mine Surveying	2 hours per week
Machine Drawing	Voluntary.

Fifth Year.

Coal Mining Engineering	1 hour per week.
Electricity applied to Mining	1 hour per week.
Electrical Engineering Laboratory Coal Mines Regulation Act	2 hours per week.
Mine Surveying	Summer course.

In the courses of the fifth or sixth year are special classes which vary considerably in different districts. Usually a man who completes the equivalent of the fourth year course has sufficient knowledge to enable him to get a manager's certificate. The first year or preparatory course is designed for those who are deficient in their common school education and, of course, may be omitted by those who have sufficient elementary knowledge. In some centres, mineralogy, geology and elements of mining are introduced into the classes of the first two years.

The principal central institutions which offer the higher classes on the free afternoons of the miners are the Universities of Birmingham, Leeds, Manchester and Sheffield, Armstrong College, Wigan Technical College, Glasgow Technical College and Heriot-Watt College.

The teachers in the lower technical classes are local colliery officials for the most part, or travelling instructors from the colleges. The higher classes are taught by the college professors and instructors.

The needs of metal miners in Cornwall are met by evening technical classes and also by the schools of metalliferous mining at Camborne and Redruth. These latter schools are under one direction and offer three-year and two-year diploma courses. Both these schools offer adequate evening technical instruction.

The evening technical schools in England and Scotland are widely diffused throughout the mining sections. In the best organized districts, such as Leeds in England, and Lanarkshire and the County of Fife in Scotland, there seems little left to be desired in the provision for evening technical instruction. It may surprise the members of the Institute to know that England is now spending more money for general and special technical education than Prussia, with about the same population, although our mother country is not achieving as great results. This is due to Germany's longer experience, stronger central government and the closer co-operation between employers and the public authorities.

Now that the coal miners in England have been forced to accept an eight-hour day, the evening technical school is much better adapted for their training than formerly. The shorter period of labour does away with the common objection that the miners arrive at the school exhausted from a hard day's work and in no state of mind to receive instruction.

Secondary Mining Education in Germany.

In Germany no boy is employed in or about a mine until he is 16 years of age. Therefore, the large majority of youths in mining districts remain in the public schools up to that age and obtain a thorough common school education.

There are two classes of schools for the training of mine officials—preparatory mining schools and mining schools proper. There are 43 of the former and 11 of the latter in Prussia and three more of each kind in other parts of Germany. These schools receive no grants from public funds, but are supported by associations of mine operators. These societies are organized to cover certain coal-producing districts. They derive the money necessary to carry on the schools by assessing the output of the various mines whose output is more than a specified minimum number of tons annually. As illustrations of this assessment, I may state that this tax in the Bochum district is about 6/10 of a mill, and in the Essen district is about 1/2 a mill per long ton.

The mining schools are maintained on a generous, but not lavish basis. The annual expense of the school at Aachen, with 83

students, is about $12,500, At Essen the school, with 160 pupils, costs about $15,000 a year. The mining school at Aachen represents a capital investment in buildings and equipment of about $75,000; that at Essen $125,000.

Youths are not admitted to the preparatory school until they are 18 years of age. They attend the classes for six or eight hours a week in the afternoons or evenings for two years. Attendance at the preparatory school is necessary for entrance to some mining schools, but not to others. The instruction usually offered in the preparatory continuation school consists of German; arithmetic; elementary geometry; geometrical, freehand, and mechanical drawing; and elements of coal mining.

The regular mining schools do not admit a student until he is 20 years of age and has had four years' practical work in mining. They accept only a limited number of students and select them by a competitive examination. The instruction consists of 20 to 24 hours a week for two or three years. In some schools, as at Aachen, the students are granted three full days a week to attend school and are paid about 50 cents a day for this time by their employers. In other schools, as at Essen, the classes are held from 4 to 8 p.m. each day in the week, after the students have worked a full eight-hour shift in the mines.

The courses are very comprehensive and the instruction thorough.

The syllabus of courses given in a representative mining school is outlined in the following table:—

Mining School, Aachen.—Courses of Instruction.

First Year.

	Hrs. per week.
German	2
Mechanics of Machines	2
Arithmetic	1
Mathematics (Algebra, Plane, and Solid Geometry, Trigonometry)	2
Machine Drawing	3
Mineralogy and Geology	2
Mining	7

Mining Regulations	2
Surveying	3
	24

Second Year.

German	2
Arithmetic	2
Chemistry	2
Physics	2
Mathematics	6
Mechanics	2
Mining	2
Surveying	3
Machine Drawing	3
	24

Third Year.

German	2
Technical Chemistry	2
Physics and Technical Electricity	2
Machines	2
Machine Drawing	3
Building Construction	2
Mineralogy and Geology	1
Mining	3
Ore Dressing	2
Mining Regulations	1
Surveying and Plotting	3
Mine Accounting	1
	24

All of the instruction is conducted on a more elementary and practical basis than that in the mining academies of Freiberg, Clasthal, Berlin or in the mining engineering departments of the technical high schools (the equivalent of our engineering colleges). The work done in these mining schools, however, is more thorough, more comprehensive, more carefully

correlated and organized, and of a higher order than that provided for the training of mine officials in Great Britain.

There is a mining school at Freiberg for metal miners. This is quite distinct from the mining academy at the same place and of a more elementary nature. It provides a four-year course of eight to eleven hours a week. It is entirely supported by the kingdom of Saxony.

Since many of the members of the Mining Institute are concerned with metal mining or metallurgy, a syllabus of the course of instruction of this school is included for their consideration:

Class IV. (1st Year).	Hours per week.
German (grammar, spelling, style)	2
Copying from dictation	2
Arithmetic and Algebra as far as simple equations, with one or more known quantities	2
Freehand drawing (drawing of simple geometric forms according to propositions and from nature) and round writing	2
Class III. (2nd Year).	
Mineralogy—Common mineralogy, crystallography, physical and chemical properties of minerals, special mineralogy, lectures on special minerals	2
Geometry (including plane trigonometry and the elements of stereometry	2
Geometry, part I (fundamentals of simple geometrical forms)	2
German as applied to mining subjects and practice in spelling	1
Arithmetic (continuation of the subjects taken in class IV)	1
Class II. (3rd Year).	
Physics (elements of applied mathematics, short course of instruction in the laws of sound, light, heat, electricity, and magnetism)	2

Mining, part I. [general] (exploration, underground methods of work and haulage, common mine regulations)	3
Descriptive Geometry, Part II. (Continuation of instruction in projections, penetrations, theory and construction of shadows, and wash drawings)	1
Drawing from mine plans	1
Mining law and workmen's insurance.	1
Geometry (continued from Class III.)	1
Mineralogy (special mineralogy) (continuation of discourses of Class III. and practice in determination of minerals).	1
Bookkeeping (introduction, inventories, estimates, simple bookkeeping).	1

Class I. (4th Year).

Surveying (instruction in the construction and use of surveying instruments, instruction in laws of measurements, simple surveys above and below ground)	2
Mining, Part II. (transportation, winding, drainage theory of ventilation, mining regulations)	2
Machine and building construction drawing (summer).	1
Machine and building construction drawing (winter).	2
Geology (Introduction) (Conditions of formation of the earth; study of rocks; vulcanism; geological action of water, ice, and wind; origin, classification, deposition and stratification of rocks; historical geology; the ore deposits and coal seams of Saxony)	2
Geological excursions in the summer	2
First aid to the injured (summer)	2
Mining machines (mechanism, hydraulic and steam machinery)	2

FRANCE.

In France there are three schools for training mine bosses and foremen. Two of these are similar and are situated at Douai and Alais. These schools require full time attendance of the miners for 6½ months each year for two years. The third

school at St. Etienne has a course of nine hours a week for one year. It is modelled after the ordinary type of German industrial continuation school.

SECONDARY MINING EDUCATION IN ITALY.

Italy does not provide any means of training for the profession of mining engineering, but does maintain two schools for the education of mine foremen. One is situated at Iglesias, in Sardinia, and the other at Caltanisetta, in Sicily. The schools require nearly full time attendance for three years. Matriculants must have a good secondary education.

SECONDARY MINING EDUCATION IN HUNGARY.

Even Hungary, which we often wrongly put in the class of semi-barbaric or decadent nations on account of the general ignorance of the peasant immigrants into America, maintains four mining schools. One of these has a six-year course of 20 to 30 hours a week for the whole year, and the other three have a four-year course of 18 hours a week.

SECONDARY MINING EDUCATION IN NOVA SCOTIA.

Leaving the subject of the secondary technical schools for miners abroad, I should like to present also a short account of the efforts of my own province in an attempt to provide secondary technical education for coal miners.

Almost simultaneously with Pennsylvania, Nova Scotia passed a law requiring certificates of competency for colliery officials. In 1888 the Provincial Government established a system of evening technical schools for coal miners. The instructors were mine officials, who were paid according to the number of their pupils that were successful at the examinations. The total expense was borne by the Provincial Treasury. The students paid no fees. The instruction covered the subjects necessary for the examinations of overmen and underground managers. The man who wished to become a manager had to acquire unaided the knowledge over and above that required for underground manager. These schools did a pioneer work of the greatest importance. Practically all of the colliery officials in Nova Scotia from the time the schools were started obtained their certificates through the medium of the evening classes.

A few years later, the province required that all hoisting engineers at the collieries should also have certificates of competency as stationary engineers. Evening technical classes were established simultaneously with the enactment of the law, and maintained by the Government.

In 1906, the Provincial Legislature passed an Act establishing a comprehensive system of technical education for the whole of Nova Scotia. The coal mining and engineering schools were handed over to the new department which was brought into being by the passing of the Act. These schools were thoroughly reorganized and put on a sound educational basis.

In the first place, a preparatory class in mathematics and English composition was introduced into every coal mining community in the province. This was necessary because the elementary education of many of the students was so deficient that they could not take full advantage of the technical instruction in the coal mining and engineering classes.

For purposes of educational administration, the coal mining area of the province was divided into five districts. In each district a mining instructor was appointed who should give his whole time and effort to the work. In the summer vacation the instructors were given special courses at the Technical College in Halifax in order to give them greater ability in teaching. The instructors were men who had had long practical experience in the mines and who had held responsible positions in the collieries. A small fee was charged for each class and a portion of the whole of the fee was refunded at the end of the year on a sliding scale basis, according to each student's attendance. This feature was introduced merely to secure better attendance. Instruction was given up to and including the subjects necessary for managers' certificates. The school term was lengthened from six to eight months. The results of this reorganization were evident in the very next examination, and the Examining Board has been able to raise the pass standard in succeeding years.

These technical schools are recognized by the miners as having been of great service to them. Practically all of the colliery officials, from overmen to district superintendents, have passed through the courses. It has enabled the native Nova

Scotian to fit himself to fill the responsible positions in the coal mines of his own province. That the officials are efficiently trained is evident from an anecdote told by the late Hon. B. F. Pearson, the principal promoter of the Dominion Coal Co. One of the early managers of the Dominion Company was Mr. Cornelius Shields. He came from the United States to Nova Scotia to inspect the coal properties for a few weeks before taking over the active management. When he first arrived in Nova Scotia, he declared his intention of bringing some mine foremen from the Pennsylvania bituminous district, in order to work the Dominion Coal Company's mines according to modern American methods. After his preliminary investigation he returned to the United States, but when he again came back to Canada the only man he brought with him was his private secretary, so satisfied was he of the capability of the Nova Scotian mine officials.

We have recently gone a step further in this matter of industrial education in mining. It was a notorious fact that the ordinary boy in mining towns waited impatiently for the day when he would be fourteen years old, or when he had attained such a stature that he would pass for fourteen. Then he straightway secured some kind of a job in the pit and joyfully fled the school. In the mine he performed the lowest order of tasks of unskilled labour. He became chiefly interested in learning how to chew tobacco and in acquiring an extensive vocabulary of picturesque profanity. These acquisitions are commonly supposed, among the pit boys, to stimulate early manhood. It was the common thing also for the boy to drop all thought of study as soon as he left the school. Thus, at the age of 20, he had often forgotten practically all that the common school had given him and was ashamed to enter the evening technical classes.

We attempted to get at the root of the evil by establishing practical courses for the boys in the public schools. It was necessary to start as low down as Grade VII., because an investigation among the students in the evening mining schools showed that the majority of the students had left school before reaching Grade VIII. Instead of teaching the boys in school to draw pretty pictures of geometrical models, vegetables, and flowers, a carefully graded course in mechanical and machine drawing was

given them. All the objects drawn were selected from the common mechanical equipment of a modern colliery. In the place of nature study there was substituted a course in mining science. This course included physics and chemistry as applied to mining, mechanics, mineralogy, and geology. These courses were not taught by the public school teacher, but by the regular mining instructors who were sent into the school to give the instruction.

It is satisfactory to state that we have already produced tangible results, although the courses have been in operation only three years. There are more boys remaining in the school to take the first-year high school course (Grade IX) than ever before. When finally they leave the public school, a large percentage enroll immediately in the evening schools without any break in their process of education. The work has received the unqualified endorsement of the boys' parents, who heretofore were convinced that the courses in the public schools above Grade VIII. were of little value in preparing the future coal miner for practical life. Public school teachers have also testified as to the efficacy of these practical courses.

In this paper an endeavour has been made to mention briefly some of the more noteworthy attempts to provide educational advantages for the miner to train him for responsibility. His needs in this direction have been generally overloooked in this country. Strict rules, intended to compel every individual in and around the mine to conduct himself in such a manner as will be conducive to his own safety and to the safety of other workers, have been issued by almost every mining corporation. In recent years all kinds of safety devices have been introduced to prevent careless or ignorant workmen from injuring themselves or others. It seems to me, however, that we have neglected the most fundamental thing of all in that we have not provided the special education to every workman which he needs in his everyday work. Education makes him intelligent and skilful, and hence more efficient. Education gives him a greater sense of responsibility and a more adequate realization of any dangers inherent in his vocation and hence more amenable to necessary discipline. Education makes him a better all-round citizen and employee. A fire boss with a manager's certificate is a

better fire boss than the man who possesses just enough knowledge to get the latter rating. All these things are true of education in general, and apply with much more force to the special technical education particularly adapted to the needs of each class of workmen.

We are standing at the beginning of a new trail in technical education in Canada. A Royal Commission will report in a few months on the investigations they have made in this direction during the last two years. They will probably recommend that the Dominion give large grants to the provinces to establish technical schools. Will the Dominion Government itself carry out this recommendation? Not without some gentle pressure. Here is this Institute's opportunity.

Last autumn the Department of Education in Ontario inaugurated a system of evening technical schools. They grant a large percentage of the expense of technical classes in the smaller communities. The expense is not great nor is it a gigantic task to start a modest, yet efficient, evening technical school in each mining centre. It needs only part of the time of a teacher, simple equipment, and the use of some rooms in the schoolhouse. The demand for such training is shown by the large number of miners in every important district who are enrolled in the correspondence schools. Here is a task for public-spirited and far-sighted mining operators.

In all the agitation for technical education in this country the dominant note has been sounded for employees in the manufacturing industries. The miners have not seriously represented their claims for attention. The common impression of technical education is that it is especially adapted for training men in the building trades, in the machine construction industries, and in the textile manufacturing establishments. I would ask the Canadian Mining Institute to join in the movement and persist until we have a technical school for miners in every mining town from the Atlantic to the Pacific. It will be of incalculable value to us if we do it immediately, while we are yet a young nation. Technical education not only makes a man an efficient producer; it makes him a more loyal employee, a man less easily influenced by passion and prejudices, and a more intelligent and independ-

ent citizen. Let us provide such means of education for the man who starts life in the mine as a boy, that he may develop his latent potentialities, and so worthily occupy the highest position for which by natural capacity he is fitted. In so doing we shall lay the strongest foundations of a powerful industry and a true democracy.

DISCUSSION.

MR. T. A. RICKARD:—A gentleman sitting next to me just now murmured, "He is talking very good sense." As I listened to Mr. Sexton I felt I should like heartily to endorse the *sotto voce* remark of the gentleman whom I have just quoted. Mr. Sexton has given us a most earnest and sincere exposition of a subject that comes near to the heart of all of us. As Huxley said: "Science is organized common sense," and if we can bring common sense to bear on a subject of so much importance we are likely to further it. He referred to three points of which I venture to speak. He referred to the distinction between the academic training school and the school for working miners. It sometimes has appeared to me that perhaps the efforts made on this side of the continent are handicapped by a confusion between the two. I like the idea of men destined for different occupations working together, but it is possible that the work of the university is sometimes hindered by those who only want to be assayers and surveyors; and on the other hand, those schools which contain mainly assayers and surveyors are handicapped by having men whose object is far wider. He referred to technical education in Great Britain. I venture to point out that the training of mining engineers in my country, and the mining industry as a whole, suffers from one regretful fact, which is that mining engineers are regarded somewhat in the light of adventurers, having some disreputable connection with the stock exchange. Of course, mining is a profession, but in England it has not got the status that it has in this country, where the development of the natural resources of a continent is before the minds of the people all the time. Then, it must be remembered that on the other side of the Atlantic, in the

British Islands, the mining engineer, even though a professional man, has a number of social strata above him, such as the landed aristocracy, the army and navy, and reserve forces. The fact is apt to contract his imagination and make him less expansive and progressive than in a country where he can at any time shake hands with the President or Governor-General without loss of dignity.

Supplementing Mr. Sexton's remarks in connection with mining education on the other side, I am glad to tell you that the Royal School of Mines has recently added a fully-equipped laboratory; and it has been impelled to do this, I take it, partly in a good spirit of emulation with McGill and Columbia and other colleges that have had good laboratories for many years. The laboratory has been erected as a memorial to Bessemer, and I believe it will prove a useful adjunct, but I am not particularly enthusiastic at any time over laboratories. My feeling and observation is that men who come from colleges where so-called practical training is made a fetish are apt to go into the field with a "big head" and with an exaggerated idea of their experience in practical matters. I take it that a laboratory is useful as a means of illustrating the lectures of the professor, but that the amateur use of it does not in any way obviate actual apprenticeship in the field. It would seem to me that a young man who has obtained a grasp of the principles of the science underlying mining, and who starts out with a profound appreciation of his ignorance of the profession of mining is more likely to progress than the man who does not understand these principles and thinks he knows it all. The knowledge of mining we get at college is insignificant; it is the mental training that is important. What is done at school is to teach a man how to learn, and he is wise who continues to learn as long as he lives. He may hope to have put on his tombstone, as was put on the tombstone of John Richard Green, "He died learning."

DR. J. B. PORTER:—A considerable acquaintance with the condition of affairs in Nova Scotia enables me to speak appreciatively of the work which Mr. Sexton has been and is doing there. I wish to congratulate the Institute, and to compliment Mr. Sexton upon the admirable comprehensiveness of his paper.

It is, indeed, a very complete review of the present status of technical education, not only in this country but abroad, and its suggestions will, I am sure, be of enormous value in the development of the movement of secondary education in this country.

DR. W. L. GOODWIN:—Heretofore, many attempts at technical education have not been signally successful, for the reason that the course of instruction had no concrete application, no definite connection or association with the occupation in life the student would subsequently follow. At the root of much educational work there is, it seems to me, a fallacy, inherited from conditions long passed away. This fallacy is that there is special virtue in the teaching of subjects that have no direct or particular connection with our activities in life. Mr. Sexton has demonstrated that this is a mistaken idea, and by adopting the opposite method, Nova Scotia has achieved success. The success, moreover, of the summer mining classes in Ontario, carried on for a number of years under the direction of the Bureau of Mines, is attributable to the practical character of the course. I trust that action will be taken by this Institute to strengthen the hands of those who are urging the Government of Canada to provide the means for the establishment of technical education in the provinces of the Dominion. This work cannot be undertaken by the provinces unaided. I was impressed by one feature in particular of the Nova Scotia system described by Professor Sexton, namely, that instruction in technical subjects was not entrusted to the general public school or high school teachers, but was undertaken by men of practical knowledge and experience. This is eminently wise and proper.

MR. R. W. BROCK:—I desire to endorse Dr. Goodwin's suggestion that the Institute take definite action in support of the movement for the establishment of technical education throughout the Dominion.

MR. H. H. STOEK:—As Mr. Sexton has stated, I was privileged on the occasion of a former meeting to present a paper to the Institute on secondary education. Since that time I have followed very closely Mr. Sexton's work. The State of Illinois has granted to the Department of Mining Engineering at the

University of Illinois the right to establish mining institutes or schools throughout the State, and a plan has been drawn up, patterned very largely upon Professor Sexton's work in Nova Scotia. Unfortunately, however, the Legislature has delayed in appropriating the money required to carry out the plans as proposed.

DR. GOODWIN:—May I suggest that a committee of the Institute be appointed to watch the report of the Technical Educational Commission, and to take such steps as may seem advisable to forward the movement.

THE PRESIDENT:—The idea occurred to me, but it would appear wise to wait until the Technical Education Commission has submitted its report. The report will be available by the time of the next annual meeting, and we might, perhaps, postpone the actual appointment of a committee until then.

A NEW DEPARTURE IN MINING EDUCATION.

By H. G. Carmichael, Sudbury, Ont.

(*Annual Meeting, Toronto,* 1912.)

About two years ago, when it was found necessary to erect a new high school building at Sudbury, it was thought by many, particularly by the chairman of the High School Board, Mr. D. Baikie and by several of the prominent mining men of the district, that some attempt should be made to give instruction in those subjects directly useful to those engaging in mining, the principal industry of the district. To meet this view, it was decided after consultation with the Minister of Mines, the Minister of Education for Ontario and with the mining men of the district, to establish a mining department in connection with the new high school. The Ontario Government promised financial aid equal to that granted to the agricultural departments of the high schools in the farming districts. The new high school building was built and equipped to meet the need of the new department and a smaller building was erected to contain an assay laboratory, a sample room, and so disposed for the conduct of work of a rough and noisy character.

The actual aim of the department is to disseminate as much useful technical mining knowledge as possible to those desiring to profit by such teaching. The instruction at present is divided into high school classes and outsiders' classes. The high school course is intended for those young men of the district who intend to follow mining and who are unable to attend the universities. The course covers five years during which the following subjects are studied:

First Year.—English, Arithmetic, Bookkeeping, Algebra, Practical Geometry (geometrical drawing), Elementary Physics, Freehand Drawing, Elementary Mineralogy, and French or German.

Second Year.—English, Arithmetic, Bookkeeping, Mensuration, Algebra, Geometry, Lettering and Drafting (plain lettering, use of drafting instruments, tracing, easy working drawings, etc.), Physiography and Elementary Geology, Physics, Chemistry, and French or German.

Third Year.—English, Algebra, Geometry, Physics (experimental heat, light, sound and electricity), Chemistry, Mining (an elementary course on methods, machinery, etc.), and French or German.

Fourth Year.—Algebra, Geometry (solid and analytic), Trigonometry (plain and spherical), Physics (mechanics and the properties of matter), Chemistry (general and qualative analysis), Surveying, Drafting (mapping), and General Geology.

Fifth Year.—Chemistry (analytical). Assaying, Mining, (methods, machinery, economics, etc.), Construction and Design (graphics, theory of structure, etc.), Ore Dressing and Milling, and Metallurgy (general and copper-nickel).

Since only a proportion of students will take the full course, the first three years of study are devoted chiefly to high school work proper and designed to give the student not only a foundation for future study, but a general idea of what mining implies as well as to develop his interest in the industry. The last two years of the course are intended to afford a working knowledge of the more important technical subjects that will confront the student after he leaves the school.

As yet there are classes in the first three years only; but it is hoped to add the fourth next autumn and the fifth the year after. The great majority of the boys attending the high school take the mining course and a class of about five is expected to take the fourth year next autumn. The total attendance of the high school classes is about thirty-five.

The average age of entry to the first year is about fourteen. The boys of the first two years are encouraged to work during the summer in the mines or smelters as water-boys, ore-pickers or at any other work they can secure. It is compulsory that the students shall work in the mines or smelters during the last two

vacations. Sudbury, in view of its proximity to important mines and reduction works, is admirably suited as a centre of mining education. Thus, there is within easy visiting distance of the school two large smelters, a cyanide mill, a magnetic concentrating works, in addition to nickel, gold and iron mines. Saturdays are devoted to visiting the mines and other plants, and so affording students the opportunity of obtaining a practical as well as a theoretical knowledge of mining.

The classes for outsiders are held at night; but instruction is given in any technical subject at other times, to any one capable of profiting thereby. The night classes held at present cover two subjects: elementary mineralogy and prospecting, and in the procedure to be followed to acquire mining lands under the Ontario Mining Act. Instruction in mineralogy covers the nomenclature of minerals and rocks, the determination of the common minerals, the ores and how they occur, weathering, etc. In the other class instruction is given on how to stake mineral claims, recording, working conditions, etc. Between ten and fifteen attend each of these classes. Instruction has been given to outsiders (in addition to the students attending the regular classes) in assaying, geology, and blow-pipe mineralogy.

The mining department is governed by a committee of twelve, half of whom are appointed from the Sudbury High School Board and half from the mining men of the district. The department is administered by a director, who instructs on technical subjects.

The mining companies operating in the locality have both approved of and rendered assistance to the undertaking. The Mond Nickel Company, for example, has established two annual scholarships of one hundred dollars each, to be awarded to the most promising candidates entering the fourth and fifth year of the course, respectively. The Hon. F. Cochrane, it should also be stated, presented the school with a library of technical books.

The courses are free and open to all.

It is proposed to award a diploma to those completing the five-year course and who can adduce evidence of having worked in or about the mines or smelters long enough to have acquired some practical experience of work in these directions.

It is not intended that the school shall compete with the mining schools of the universities; but it should serve a purpose of its own in the dissemination of useful knowledge among a clas either unable to afford or for other reasons prevented from securing the advantages of university training.

In comparing the high school course with the regulation courses of the universities the chief points of difference are, that preparatory general education is not sharply separated from the technical but generally leads up to it; that the course is shorter, and that less stress is laid on mathematics. The serious technical work begins with the fourth year when the student has very nearly the same grounding as is required for matriculation to the universities. The course is covered in two years of ten months, against four years of seven or eight months at the universities; hence the actual difference in point of time is not so great as might at first appear. Moreover, the students will complete this course at a younger age than that of the college graduate, and so should be more willing and better able to start actual work at the very bottom of the ladder.

The idea of attaching a mining course to the high school curriculum is novel, in Canada. Since its initiation at Sudbury, a similar department has been added to the high school at Nelson, B.C., where conditions are very similar.

SANITARY CONDITIONS IN MINING CAMPS.

By Chas. H. Hair, M.D., Cobalt, Ont.

(*Annual Meeting, Toronto, 1912*)

The science of hygiene has made rapid progress during the last decade; and as time goes on further advances in sanitation and its practical application to the varying conditions of life will do more to lessen the death rate than all the discoveries of curative, medical or surgical science.

It is eminently important that in the new towns springing up in the vicinity of mines and at the mines themselves early measures should be taken to ensure satisfactory sanitary conditions. In such localities the opportunities are peculiarly favourable for the application of improved methods of scientific sanitation. In recently established mining camps, however, this essential provision has generally been overlooked until its necessity is brought home by an epidemic resulting in an appalling loss of life.

Both towns and settlements in the vicinity of mines, as well as the mines themselves should be under government or other official supervision, and new townsites should be inspected by a competent sanitary officer, such as the Chief Medical Officer, or preferably by a commission to include the Provincial Medical Inspector and a representative or member of the Canadian Public Health Association, who shall be responsible for ensuring that the provisions in respect of water supply and sewage disposal are adequate. The promiscuous building of towns, moreover, should not be allowed, while the authorities should also require that in establishing divisional points on railway lines, the choice should not be determined without due regard to considerations of future water supply and sanitation.

In this paper it is proposed to discuss and to suggest the best methods for ensuring sanitary conditions.

Water Supply:—Water may be a principal source of disease. The only reliable information respecting the suitability and purity of drinking water is that afforded by a bacteriological test. If the mining camp is in an evergreen country the water will contain a high percentage of organic matter or chlorine and hence is a highly suitable culture medium for bacterial infection of intestinal or other origin, which may readily be carried into the water of a lake by bathers or by drainage. It is only necessary to state that the excreta of one who has had typhoid will show the presence of the germ for from six months to two years. The water of springs, unless surrounded by a sand or gravel area is not naturally filtered, but is often only rainfall circulating through an organic soil to a clay strata beneath, re-opening at the surface at a lower level. This source of supply will often carry infection for a considerable distance.

If then there is a water supply on the mine property it should be the first duty to protect it in every way from possible contamination. If, however, there is a suspicion of contamination, the first and most ready method of purification is to boil all drinking water and water used for cooking purposes. All drinking vessels or dishes should be similarly treated. One of the best means of purification is that advised by Dr. Nasmith and Dr. Graham, of the Provincial Board of Health, as follows: "A level teaspoonful of chloride of lime should be rubbed into a teacup of water. This solution should be diluted with three cupfuls of water, and a teaspoonful of the whole quantity should be added to each two gallon pail of drinking water. This will give .4 or .5 parts of free chlorine to a million parts of water and will in ten minutes destroy all typhoid and colon bacilli or other dysentery-producing organisms in the water. Moreover, all traces of the chlorine will rapidly disappear." One objection is the taste of the chlorine, to which, however one will soon become accustomed.

All water supply should be protected by prohibiting bathing in lakes, drainage of any sewage from any source, and requiring all buildings to be at least 100 feet from the high water mark, while outbuildings should be considerably more distant.

Garbage Disposal:—Various methods have been employed for the disposal of garbage at the mines and in the new towns; but the majority of the means adopted are defective. At the mines the feeding of garbage to hogs is a practical, profitable, and not objectionable method of disposal, provided the animals are maintained in good health. But this only disposes of a part of the garbage. It is important in addition that liquids should be carried off by means of a drain to a tank, lined with cement or cedar, with sub-soil drains leading therefrom. Any solids, such as cans, bones, etc., should be burnt. All manures in like manner should be removed and burnt.

Sewage Disposal:—Unless sewage is properly disposed, it becomes the source of the disease-producing germs that contaminate the water supply or are carried as infection by house flies. In new mines or camps no attempts are usually made to provide for sewage disposal; rather it is allowed to take care of itself. Such provision should be the subject of immediate attention. The first step then is to erect a box closet, the box of which will hold excreta whether solid or liquid. The old earth or pit closet is no longer regarded as sanitary, since it may readily contaminate the wells or other sources of water supply in the vicinity. The box containing the excreta should be cremated at frequent intervals. The oftener the box is renewed the better. Directly, however, a water supply under pressure is obtainable, providing the soil conditions are favourable, the ideal method for the disposal of sewage is that afforded by the flush closet and the septic tank.

Ventilation:—After a camp ha been established for some little time, there is often a tendency to overcrowd the sleeping quarters. Bunk houses should therefore be so constructed to admit of adequate ventilation, and instead of one large room there should be a number of smaller ones. The crowding of men into one apartment may readily result in the rapid spreading of any infectious disease that may be prevalent.

The House Fly:—Ever since the plagues of Egypt, recorded in the Book of Exodus, a hazy belief has been held that the house-fly was more or less a carrier of disease; but it is only lately that the real danger from this source has been appre-

ciated. A few years ago a committee appointed to consider the question of water pollution in New York harbour made public certain facts that classed the fly as one of the most dangerous enemies of the human race. It was shown that a fly was capable of conveying from place to place innumerable faecal bacilli (as many as 125,000), and estimated that from two to seven thousand deaths from diarrhoeal diseases and fifty thousand deaths from other diseases were attributable annually in New York City alone to infection from this source. Since this report was issued a general crusade against flies has been undertaken, under the direction of a committee formed in February, 1910, and representative of several States of the Union. It is believed that the fly plague is not one that must be endured as a visitation of Providence, but may be stamped out by the adoption of systematic measures to ensure cleanliness. The fly is bred in, lives, and thrives in filth. If no filth is allowed to accumulate in the neighbourhood of human habitation, the pest of flies will cease, for they do not ordinarily stray from their breeding places and their resources of food supply. The conditions obtaining in new towns and mining camps in Northern Ontario, have been ideal for fly breeding, and having regard to the habits of the insects, one can but wonder that infectious diseases have not been spread more widely. There is no doubt, however, that much of the typhoid has been due to flies; it will decrease in proportion to the efforts made to get rid of them. It is better to prevent their germination than to attempt their extinction. When flies are once in the house, the best method of killing them is, possibly, the use of two teaspoonfuls of formaldehyde to a pint of water placed in plates or saucers in each room. I am inclined, however, to question the efficiency even of this method. I have said nothing respecting screens. These are merely useful as a protection from the fly; what is more important is its extermination, which, as already stated, may be accomplished by observance of the laws of cleanliness.

VENTILATION IN METAL MINES.

By Frank C. Loring, Toronto, Ont.

(*Annual Meeting, Toronto,* 1912.)

Pure air is universally available. It surrounds the earth. Even in the most crowded places it can be obtained by reasonable effort. All recognize its importance as an element in the creation of the maximum of mental and physical energy in animal life.

Notwithstanding this universally acknowledged fact, none of the natural rights of man, the observance of which should be the duty of all, is more generally ignored or more ignorantly utilized. In the home, the office, the theatre, church, street car, on the railway train; the careless, ignorant lack of proper use of this necessary element is almost universal.

In mining, all concede that proper ventilation is of utmost importance. In coal mining especially, both because of the need of pure air to breathe and for expulsion of poisonous and inflammable gases, special provisions are made for ventilation. In coal mining regions laws and regulations are formed providing for this. They are found necessary owing to the criminal carelessness of both employer and labourer. Yet, notwithstanding these regulations, the world is often shocked by the frequent recurrence of the horrors resulting from fire damp and choke damp in coal mines.

And what is the condition in metal mines? Is the natural right of every human being to breathe pure air sufficiently and practically recognized? Assuredly no! Wherever metal mining is conducted proper mine ventilation is presumed to be compulsory. The laws governing the matter, however, are so general that they can be easily evaded if desired. Some laws provide for air circulation between levels and to the surface by means of

shafts and other connections, not to exceed certain stipulated distances apart. After these connections are made, they are usually efficient in their immediate neighbourhood; but not always. They are often, however, several hundred feet apart, and before air circulation is thus created weeks and often months intervene wherein the miner is compelled to breathe poisonous gases before they bring relief. Every manager is familiar with the evil results of this lack of pure air. There are few mines that have been operated for any considerable period wherein men have not been suffocated or permanently injured by powder or other poisonous gases. The daily unrecorded injury is continuous and must and does exert a serious effect on the victim during his life. Many cases of heart disease, consumption, and other chronic ailments can be directly traced to this cause.

I quote from an article in the report of the Bureau of Mines, Mining and Mine Inspection of the State of Missouri, for 1909. The author says:

> "We are all familiar with the disease known as miner's consumption and its deadly ravages among the mine workers of this and other districts.
>
> "I have no statistics upon which to base the assertion, but I am sure that the number of miners who die annually from this disease is far greater than the number killed in mine accidents. The fact that workers in hard ground are more subject to it than those in soft ground, and machine men more so than other ground men, leads me to believe that it is caused by the constant breathing of air laden with rock dust and lamp smoke. It should also be remembered that the large quantities of explosives used in the hard ground mines seriously vitiate the air and leave a residue of noxious gases. Improved ventilation, sprinkling to lay the dust and the use of smokeless lamps is the surest solution of the problem, the need being for the application of well known practices, rather than anything new."

There is no intent to enumerate the various methods of ventilation—whether by blower, by exhaust fan, by drill hole, or other means. They are numerous, efficient and comparatively inexpensive, both as to cost and operation; but such is the perversity of human nature that both the injured and the one who injures are often content to bear these ills rather than take steps to cure them. Occasionally some more serious calamity with consequent liability, arouses the attention of the employer, or the indignation of the employee or the public, whereupon temporary, tentative steps are taken to provide a remedy. This is, however, seldom gone into with an earnest endeavour to permanently cure

the evil. I have examined many works on mining, in some of which the closest details are considered regarding far less important matters and I have not found one which sufficiently treats of the subject of ventilation from a humanitarian standpoint, or its bearing on the economics of mining. The records of mine accidents are meagre as to the ratio of deaths by suffocation to all casualties. It is undoubtedly high. The report of the Inspector of Mines of Marquette, Mich., attributes 25% of all fatal mine accidents for the year ending September 30, 1911, to that cause. Lists of accidents in reports from other states show that next to deaths caused by falling rock, those by suffocation are the most numerous. Apart from this, there can be no record of the permanent injury and shortening of life caused by constant breathing of impure and poisonous air, a direct result of imperfect ventilation.

That which I have stated will, I think, be generally admitted as true; but will recognition have any result on the future actions of anyone who should be interested? I fear little or none. Humanity, whether it be employer or employee, is and always will be careless of intangible and indefinite dangers. We will continue to deplore the evils of bad air, but we are little apt to improve conditions from humane motives.

It is necessary to appeal to something more substantial, to be convinced that as a matter of business—of dollars and cents—more attention should be paid to pure air and proper ventilation. There are few mines wherein, if the attempt were made, it could not be shown that actual profit would ensue by the introduction of more complete methods of supplying air and exhausting the poisonous gases, than provided simply by the means of ordinary connections. It is usually the custom to drive levels several hundred feet without any provision for expelling gas, other than possibly the crude, highly expensive method of blowing out with compressed air. Often even this is not done. The additional cost per foot of drifting, or ton of ore produced, of a pipe maintained to within a few feet of the face, which could easily be protected by a moveable timber screen and connected to the surface with an exhaust fan, is infinitesimal. In shafts, raises, and stopes, often the poorest ventilated parts of the mine, the additional

cost of a pipe so constructed that it could be unjointed and removed during blasting and replaced immediately thereafter would be unimportant; and if a record were made of the increased amount of labour both as to actual time and continued efficiency, which would be secured thereby, it would be found that the profit would be substantial. There are mines wherein these methods are practised to some extent; but there are few wherein they are carried to the logical limit. The profit resulting from constant increased efficiency, as well as by decrease of time lost in waiting for workings to clear, would more than offset this additional expense. Undoubtedly a large part of the underground force loses from a few minutes to an hour, or even more per day, either in absolute inactivity or by less work resulting from poor ventilation. A comparatively small daily loss would balance a goodly amount of investment of capital and of additional cost of operation of a complete ventilating plant.

Aside from the economics of the ordinary daily operation, there is the advisability of providing as far as possible for the liability of employers in cases of fatalities caused by asphyxiation. Not only would there be fewer such cases with the consequent financial liability, but if it could be shown that every possible effort had been made to properly ventilate the mine, it would be more difficult to fasten the liability on the employer.

If it can be proven (and there should be little difficulty in many cases) that a miner had contracted consumption, heart disease, or had been otherwise physically disabled by having breathed poisonous, dust laden, or otherwise impure air in a mine, it seems logical that a court would fasten the liability and consequent damage on the employer. There is undoubtedly an increased tendency among legislators and in the courts to place greater and greater responsibility on the employer for the safety and health of the employee.

A closely allied subject is that of dust created in drilling dry holes such as uppers in drifts and stopes. The sharp, often glassy, dust created is exceedingly injurious to the delicate air passages. The miners should be provided with proper dust

guards and they should be compelled to use them—often a difficult matter. There is little expense in rigging up a spray which would effectually keep down the dust. Machinery companies advertise such an attachment. Here is another phase of employers' liability and responsibility well worth consideration.

EARLY MINING ON THE COLUMBIA RIVER, BRITISH COLUMBIA.

By Frank L. Nason, West Haven, Conn.

During the years 1895, 1896 and 1897, the writer was engaged in hydraulic mining in the section known as the "Big Bend Country," on the Columbia River, some seventy-five miles north of Revelstoke. Among the miners in his employment were a number who had participated in the first "rush" to the district rather more than thirty years earlier. This "rush" to British Columbia was a direct sequel to the California gold excitement of "forty-nine." The exodus from the latter field dated from about the year 1857, when the gold production in this State declined from $87,000,000 to $50.000,000. The pioneer miners and prospectors in their wanderings, followed a golden trail, for more or less gold is found in the gravels of the Pacific slope, from Lower California to Alaska. The following account of early gold mining on the Columbia River was related to the writer by one of his employees:

"The crowd of gold-seekers after prospecting every branch and arroyo of the Sacramento, proceeded northward, some presently reaching the Columbia River. Here the conditions of travel were ideal, for the river was navigable for canoes, and the abundance of salmon ensured an ample food supply. On the way, no "bonanzas" were found; but the result of panning was sufficiently encouraging to stimulate search further afield. At the Cascades, it was necessary to portage; but above here to the Dalles the going was easy. From the Dalles to the Arrow Lakes, the water is swift, but good "colours" continued to be found, and so in spite of all difficulties, the journey was continued. Nevertheless, four years passed before the party arrived at what is now Revelstoke. Seven miles above Revelstoke, at the mouth of Six Mile Canon,

a bar was "struck" on which the party worked for two years, but without meeting with any notable success. In 1864, the claim on Six Mile canon was abandoned, it being decided that there were greater possibilities of finding rich ground in the "feeders" that came down from the mountains. The first real feeder was Downie Creek, and here a few rich pockets were found, as also on Cairnes Creek. It was then concluded to explore higher upstream, and so Priest and Death Rapids and Steamboat ripple were faced, and the party finally fought its way to the mouths of Gold Stream and Smith Creeks. Both streams promised well, and after holding a council to discuss plans for the future at "Pilgrim's Tree," which still bears the date 1865 carved on its trunk, a decision was reached to split the party in two, one to prospect Smith Creek and the other Gold Stream. I was with the Smith Creek party, and at first we were more successful than the other, my partners and myself taking out six thousand dollars in six days from one pocket in "Pot Hole" creek. Later, however, the luck changed and better results were obtained from Gold Stream. McCullough, Chance and French Creeks were found and worked. But it was only after five years of hard work that the one important find in the Big Bend was proved. The miners on French Creek in 1870 were depressed; in the winter of 1871 two of the men left the camp, announcing their intention of returning to the United States. Later it transpired that they had taken with them bushels of coarse gold, and were merely awaiting their opportunity of covering the bench with claims. Crowds, men, women, and even children, arrived on the scene; and in '72 or '73 a little steamer was navigating the Columbia River to the foot of Priest Rapids, where a small town, La Porte, was established.

"Between 1860 and 1875 the Big Bend Co. produced gold to the value of about $5,000,000, of this about $4,500,000 was produced in three years from French Creek. There is no longer a town of La Porte, and the steamer made its last journey in 1876."

The "Pilgrim's Tree" to which reference is made above, was shown to the writer in 1895. It is a white cedar, the diam-

eter of which is about three feet. On its trunk is a scarf, of about 12 by 6 inches, and, in 1895, 2 inches deep, representing the growth of thirty-five years. On the weathered scarf were illegible pencil marks, although the date, 1865, was fairly legible. At French Creek, the writer saw among the charred ruins of log houses, broken fragments of freestone that might well have once formed the bed of a billiard table. These are the sole evidences of early gold mining effort.

Meanwhile the building of the Canadian Pacific facilitated the exploration of the Big Bend. The railway contributed both men and supplies to this end. The supplies were an involuntary contribution. In every miner's shack from Downie Creek and onwards, were to be seen picks, shovels, hammers, anvils, drill steel, pick and hammer handles, cases of powder, caps and fuse, each bearing the stamp of the "C. P. R." With the completion of the Grand Trunk Pacific, the whole of the Big Bend country will become readily accessible.

That there are numerous deposits of lead, zinc and copper, the writer can vouch, since in the gravels of the placers, galena, sphalerite and copper ores were a large constituent of the black sands. Moreover, the galena and sphalerite proved to be highly argentiferous, the copper ores were found to carry gold. It may be remarked in conclusion that there appears to be no reason why the Selkirks, the Gold and the Coast ranges should not be as rich in minerals above as below Revelstoke.

THE JOPLIN MINING DISTRICT.*

By W. W. Boyd, McGill University, Montreal.

Introduction.—The zinc mining area in Southern Missouri and Northern Arkansas, which for many years has been commonly known as the Joplin district, has been continuously worked for a very long period, and is one of the best known in the United States; and as is very natural, there is an extensive literature of mining, ore dressing, and metallurgy devoted to it.

The writer of the present paper has no intention of attempting to review this literature, or to deal with the district at all exhaustively, but he has felt that it might be desirable to submit a general statement of the conditions and methods in the district, and in doing this, he has drawn chiefly upon notes taken during an extended visit to Joplin and its vicinity during the summer of 1911: but he has felt free to supplement his own notes by matter drawn from previous publications.

Geographical Position and General Topography.

Joplin district lies between 94° 15′ and 94° 45′ W. longitude, and between 37° 15′ N. latitude, thus including two 15′ quadrangles. Its length approximates 27 miles from east to west, and width about 17 miles, the area covered being 476 square miles. This district lies in what is known as the Ozark region, a short description of the general topography of which now follows.

The Ozark uplift topographically is a low asymetric dome of a roughly elliptical shape, which lies in southern Missouri and northern Arkansas. It is bounded on the north and the northeast by the Missouri and Mississippi rivers, respectively, on the west by the Spring and Neosho rivers, and on the south and southeast by the Arskansas and Black rivers, respectively.

This Ozark region is divided into four districts: (1) Missouri district, in which Leadville is situated, and which is essenti-

*Honourable Mention, Students' Competition, 1912. This paper has been abbreviated for purposes of publication in the Transactions.

ally lead producing; (2) central Missouri, producing both lead and zinc; (3) the Missouri-Kansas district, which is zinc-producing; and (4) the northern Arkansas district, producing mainly zinc and a small proportion of lead. The Missouri-Kansas district is characterized by the absence of well defined fissures and by the common occurrence of large bodies of ore of slight horizontal extent known as "runs," or in comparatively thin tabular bodies of great horizontal extent, known as blanket veins or "sheet ground." The ores consist of lead and zinc sulphides, occurring in the runs mainly as accrement to miscellaneous chert breccias, and in the sheet ground commonly as horizontal layers between slightly disturbed beds of cherts.

The Joplin sub-district comprises a part of the Missouri-Kansas district, lying near its west margin partly in Kansas and partly in Missouri.

GEOLOGY OF THE OZARK UPLIFT.

As will be seen by the accompanying sketches, the Ozark uplift is, structurally as well as topographically, a broad low dome of elliptical outline. The structural crest which lies north of the Boston mountains follows a curved line from the St. Francis mountains to Cedar Gap. It is situated somewhat eccentrically to the whole region and from it the rocks slope gently outwards.

Along the southern border of the region the slope becomes quite steep, and the strata exhibit a pronounced monoclinal structure, but in the north the dip is more uniform and quite gentle. The rocks of the region, with the exception of some of the peaks of the St. Francis mountains, are of sedimentary origin.

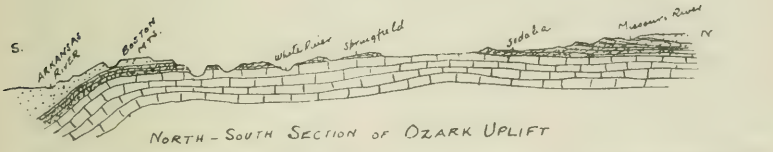
The Cambrian and Cambro-Ordivician rocks which underlie the dome are distributed in concentric bands around the St. Francis mountains, while outside of the central area of these older rocks the Devonian, Mississippia nand Pennsylvanian in turn form outcrops, except at the southeast where they are covered by the overlapping Tertiary of the Gulf plains.

In the southwest the belt of the Missouri deposits spread over a great area, approximately 80 miles from N.W. to S.E. and 160 miles from S.W. to N.E. Within this large area all the important

zinc camps of the southwest occur. The rocks are prevailingly limestones with shales in minor quantities, the principal formation of the district being the Boone, which contains large amounts of cherts, in part in small nodules in the limestones and in part segregated in distinct beds.

The Pennsylvanian rocks, which overlie the Mississippian on the outside border, mark the outward limit of productive territory, and consist mainly of shales and sandstones with coal beds and thin limestones.

GEOLOGIC SECTIONS



NORTH-SOUTH SECTION OF OZARK UPLIFT

CAMBRIAN LIMESTONES OVERLAIN BY DEVONIAN SHALES AND CARBONIFEROUS STRATA

EAST-WEST SECTION OF OZARK UPLIFT

PRE-CAMBRIN ROCKS CROPPING OUT IN ST FRANCIS MTS OVERLAIN WITH DEVONIAN SHALES AND CARBONIFEROUS STRATA.

The Joplin district lies on the northwestern slope of the Ozark uplift and is included in the more plateau-like portion of the region. The rocks are for the greater part sedimentary, and belong to the Boone and Cherokee formations. The Cherokee, stratigraphically higher than the Boone formation, is confined largely to the west and northwest portions, although patches are distributed throughout the district; while the Boone formation, composed of limestones with interbedded cherts, covers most of the district.

ECONOMIC GEOLOGY OF THE JOPLIN DISTRICT.

The mineral occurrences here represent a great variety, but it is sufficient to mention those only for which the Joplin district is notable. These minerals may be classified as: (1) Those which are of economic value, namely, galena and its secondary product cerrusite; sphalerite accompanied by smithsonite and calamine. (2) The minerals which have not any great economic value, such as marcasite, pyrite, and chalcopyrite, calcite, dolomite, and quartz; also such products of weathering as limonite, gypsum and greenockite; and barite, wurtzite, and millerite.

Hydro-carbon compounds are found throughout the deposits, and coal occurs in fragments throughout the ore bodies in the Cherokee shales of Kinderhook age in which the ore bodies occur. In most of the deposits a black viscous fluid called by the miners "tar" is found, and though usually inconsiderable in quantity it sometimes occasions difficulties in the mining and milling of the ores.

The most important mineral of the district is sphalerite, locally known as "jack." It occurs in crystals and crystal-aggregates lining cavities, and in grains impregnating and disseminated through large bodies of shales and jesperoids. The ore as milled varies very greatly in percentage of zinc content; but the milled concentrate averages 57 per cent. zinc and about 1 per cent. iron.

Though not nearly as important as sphalerite, galena, locally known as "lead," occurs in grains and crystals, impregnating shales, limestones, jaspers, and selvage; as crystal-aggregates on walls of cavities; massive in seams; and also as a cement in chert breccias. The galena of this district is non-argentiferous, in a commercial sense, containing only from a trace to 1.75 oz. per ton of silver, but there is annually recovered from Joplin lead a certain unknown amount of silver, for certain of the refineries find it advisable to add a proportion of lead from the Joplin district in the process of refining other argentiferous lead ores.

The marketed lead ore contains about 80 per cent. lead, the impurities being gangue materials and associated minerals of nearly like specific gravity, such as iron sulphide and sphalerite.

As regards the two zinc products, smithsonite and calamine, both are known locally as "silicate" and the ore marketed as such falls considerably below the pure theoretical value of 54 per cent. zinc, being contaminated with gangue materials. Although a considerable quantity of smithsonite is mined and sold as "silicate," it is seldom found below a depth of 50 feet, and (with the exception of sphalerite), other ores of zinc by reason of their solubility, are seldom found at less depths than 15 to 20 feet, so that their occurrence is limited to a shallow bed.

The Shapes and Occurrences of the Joplin Ore Bodies.—All the ore bodies of this district, whether simple or complex, fall under two general headings; (1) Runs and their modifications, and (2) blanket vein deposits, locally known as "sheet ground." These deposits occur as large irregular bodies in cherts and limestones, which are usually brecciated and cemented or impregnated by dolomite, calcite, or sphalerite, which carry important quantities of sphalerite, galena, and iron pyrite. They occur in the Boone formation, associated with forms of fracturing and brecciation; and as stated above have two general forms, the breccias proper and the blanket veins or sheet ground deposits. In the latter the ore occurs in thin sheets between nearly horizontal beds of cherts, the brecciation being unimportant.

The "Runs."—Under the heading of runs come simple runs, complicated or compound runs, and "circles." Simple runs are usually irregular elongated bodies of ore extending along an approximately straight line and maintaining a fairly constant level. They are associated with disturbed strata which was displaced by minor faulting and other movements. Simple runs are not common. Nevertheless, most runs are highly contorted and follow complicated curved paths.

These complicated and more or less circular bodies owe their many contortions to very complicated underground draining, much minor faulting and other movements. Under the heading of more complicated runs come circles, which as their name implies, are rudely circular or elliptical bodies of ore. They occur in all the more important camps of the district, namely, Neck City, Oronogo, Webb City, Joplin, and Galena.

Blanket Veins or Sheet Ground Deposits.—These deposits are nearly horizontal bodies of ore, sometimes of great area, which are developed parallel to the bedding planes of the rocks. The ore of the sheet ground, which has both a lead and zinc content, is fairly uniform for considerable distances as in a single mine, but varies greatly at greater distances. As a rule, the ground in these sheet deposits is quite firm, only scattered pillars being used in mining to support the roof. For instance, in one of the mines in the Continental Zinc Mining Co.'s lands, which the writer visited, 10 per cent. of the total ground area was left as supports for the roof. As regards the relative amount of ore in the runs and the sheet ground, the ore in the latter type of deposit is very much poorer, although on account of the uniformity of the ore, the ease with which the ore can be mined and the mineral extracted (due to the relation to bedding planes) some of the largest and most paying mines are worked in this ground. With ores as low as 2 to 2.5 per cent., mines are now being worked in sheet ground and from this percentage the ore runs up as high as 25 per cent. in places. As a rule, the majority of sheet ground deposits do not average above 6 per cent. or so.

*Genesis of the Ore Bodies.**—Briefly, the minerals were carried down in solution from the Pennsylvanian formation of shales, which originally covered the whole of the Ozark uplift and were precipitated from solution in the strata in which the ores are now found by the agency of hydro-carbons, evidence of the existence of which has been amply demonstrated.

EARLY MINING IN JOPLIN.

Actual mining in this district appears to date from 1850, and was confined to mines worked for lead only, in Jasper and Newton counties. From 1850 to 1854, about 340 tons of lead ore are stated to have been produced. In 1854, the first lead furnace in this district was established, and throughout the Civil War this furnace was operated spasmodically by the Confederates and Federals alternatively.

Mining in this district did not begin to assume any dimensions of importance until the advent of a railway at Minersville

*For a full report see Joplin Geologic Folio No. 148, p. 18.

—now Oronogo—in 1870; and from that time the importance of the Joplin district as a zinc camp has been steadily increasing. Zinc silicate was first shipped in 1870, and from the mines around Joplin, sphalerite began to be shipped in 1873. In 1870, the mineral production of the camp changed from lead to zinc, and the trade has now reached a point where the zinc predominates, the ratio being 7 to 8 zinc to 1 lead.

Joplin, in the first place, was essentially a "poor man's camp." But, at the present time, the camp represents a multitude of mine mills and buildings, although the conditions will never permit of its being a "consolidated" mining camp, controlled by one or two companies.

The surface ore bodies of this camp are shallow and pockety, but often very rich, so that conditions are particularly favourable to mining on a small scale. The nature of the deposits, however, makes the investment of any considerable sum of money a risky procedure, and the larger investments made in this field are confined to the "sheet ore mines," which represent a more permanent type of mine. With the recent discoveries of large bodies of ore in sheet ground at depth, large mills (of 1,000 tons per 24 hours' capacity) are being established.

ZINC PRODUCTION AND TRADE CONDITIONS.

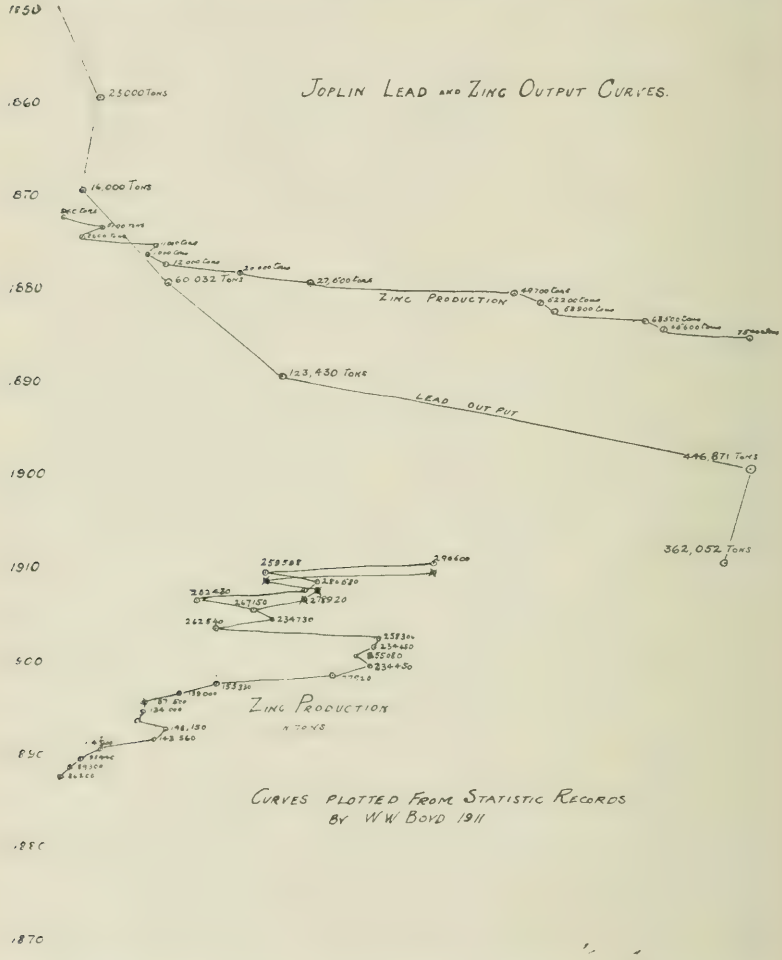
The accompanying diagram shows the fluctuations in the zinc production in the last few years. The figures being taken from the journal of Frank Eberle, Joplin, Mo. The record production was made in 1907, but in 1908, as a result of Mexican competition, the output seriously declined.

In 1909, protection was afforded the industry by the imposition of a duty on the Mexican ores, and during the latter half of the year general confidence and activity were restored.

PROSPECTING IN THE JOPLIN DISTRICT.

In the early days of mining, when the surface "pockety" ore bodies were being worked, the prospecting was conducted entirely by shaft sinking on the ore body. This was found to be cheap and practical. With the advent of "sheet ore" mining, another

method of prospecting was followed and for the purpose the churn drill was introduced. This type of drill was found to meet every requirement, although there are few districts in which the capacity of a drill is taxed more than in the Joplin country.



So varied is the character and thickness of the strata that not only do drilling conditions differ in different localities, but almost as widely different conditions may be encountered in holes drilled within a few feet of each other. The sheet ground, however, pre-

sents a quite marked degree of uniformity. The ground met with in drilling varies greatly—soft ground, caves, cherts, limestones, and calcite filled cavities, are met with in such a way that it is impossible to prophesy the conditions of the ore body until drilling has been undertaken.

The churn drill, it may be admitted, has many disadvantages. For instance, most of the drilling is done by contract, and, of course, the speed of drilling is a great factor, not always assisting towards the accuracy of the hole. Again, frequently the operator is rather lax in sludging out the hole often enough, and as the ore often lies in thin streaks of very rich ground, and the ore-bearing ground is usually much softer than the surrounding rock, the result is misleading.

The advantages of the churn drill are obvious. It is the only drill which can really be said to cope successfully with the great variety of conditions, and the very hard and soft rocks about here. It is cheap, rapid, and, for prospecting an ore body of the sheet ground type, is an especially excellent type. As already stated, the churn drilling is done by contract. The drillers, including outfit, may be hired at from 90c. to $1.25 per foot, depending on the nature of the ground. The contract price of the churn drillers prospecting on the lands of the Continental Zinc Co., was at the time of the writer's visit, 85c. per foot, and on the statement of one of the operators, this drilling costs the drillmen roughly 65c. per foot. So far core drills in the Joplin district have not proved notably effective, but extensive experiments have been undertaken to find a suitable type. Some years ago diamond drilling was attempted, but was not particularly successful.

MINING METHODS.

In the following notes on mining methods and conditions at a typical small mine, a detailed description has not been attempted.

The A. B. C. Mine.—The mine has an output of 40 tons of zinc concentrate per week valued (June, 1911), at about $38.00 per ton. Being in the "pocket" formation, a rooming system of mining is followed. The drills used are of the Ingersoll-

Rand type, having a very strong back pull in order to prevent jamming in calcite pockets. Fifty per cent Dupont powder is used. The shaft is small (About 4′ x 4′). The hoisting machinery is placed immediately above the mouth of the shaft. No timbering is required where the roof is hard, but where the chert has been cut through to the softer ground the roof is supported by timber pillars and square sets. Shaft sinking costs from $2.00 to $10.00 per foot, depending on the nature of the ground.

This mine employs about 24 men, including two mill men.

The surface buildings consist of power house, storage bin and mill. In the power house there are two 250 H.P. boilers which are capable of supplying more power than the mine requires. The drills are supplied with air by one small 2-stage 4-drill Ingersoll compressor. The ore bin has 400 tons capacity. The "chats," or mill tailing, are now an additional source of revenue, as they are used for concrete work and for railway ballast; and are sold at the dump for 11c. per cubic yard, of which the miner gets 1c. The hoisting is done from an engine in the headframe. Buckets are here and almost universally in the district employed for hoisting, and are not dumped, but transferred to the surface cars and trammed to the mill. The buckets are 2.5′ x 3′.

A rough outline of the mill follows:
400-ton ore bin.
Blake crusher.
Rolls.
Two 4-compartment jigs.
Rolls.
Two Wilfley tables.

White pine shingles are employed for wedging the rolls. These shingles cost $1.75 per bundle and the bundles average eight to the thousand feet. The tails are elevated and run out to the chats piles in small launders, the water is then drained off into a large reservoir and used again. As these mills are built on level ground the ore is passed through them by means of elevators. This is an excellent method in small mills, as it reduces the number of attendants required. The wages paid at this mine per day of 8 hours are as follows:

Machine men, $2.75; muckers, $2.25; trammers, $2.25; head mill man, $3.00; mill men, $2.00. One mill man will do all the work in this mill in cool weather, but as the temperature gets very high in the summer three men are required.

The statistics of mines producing ore from the sheet ground deposits, show that this branch of the industry has been growing rapidly for the last ten years, and that in the year 1908 it produced nearly half the concentrate of the district. During the last year, however, mine operators have asserted that at prevailing prices it is not possible to profitably operate these mines, and it is true that in the majority of cases of mines working the sheet ground, the margin of profit is small. One reason of this is the decided leanness of the sheet ground ore. The probable average of the zinc and lead concentrate has been from 2.5 per cent. to 3 per cent. of the ore mined, which at an average value of $40 per ton of concentrate represents a value of $1.00 per ton for crude ore. Another reason is that although the price of concentrate has not advanced, the cost of mining has increased considerably. This is not, however, due to bad mining practice, but to the increased costs in recent years of labour, powder and fuel.

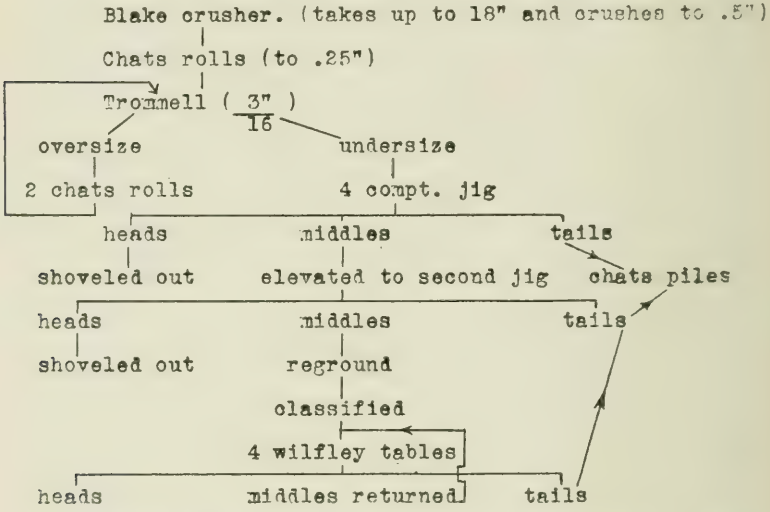
When one considers the relative costs of mining and milling of the free ore and the sheet ore, it is not surprising that in certain instances the sheet ore mines are unable to compete. In the more successful "free ore" mines the expense of explosives and machinery are very low. In fact, "free ore" mining is often done as cheaply as $10 to $12 per ton of concentrate recovered.

At the moment the interest of the prospector and the operator has been turned towards discoveries of new ore bodies of the cavernous type, some of which are said to be of very great richness. These, although rich, are likely to prove very irregular and in time the more reliable characteristics of the sheet ground deposits will again make them attractive as an investment. The ore can easily be discovered and located with a few drill holes and this in connection with the large extent of many of the sheets, has tempted even the most conservative of companies into this field and both a great many failures and a great many successes have resulted. The failures are particularly evident as

all too many mills and extensive workings have been abandoned or left idle.

A description of another mine, having a larger output (16,000 tons a month) may prove of interest. Here the total average cost of mining and milling is stated by the manager to be $0.85 per ton of ore, and the average cost of milling 22 cents.

The mill is built on level ground, a system of elevators being employed. The mill is roughly as follows:



The shaft has two compartments with balanced hoist, and is 210 feet deep. There is just one level in this mine which is mined in the form of a big room of nearly circular form, and of which the shaft is the hub. Two large pillars on either side of the shaft protect it, and the rest of the roof is supported by ore pillars, which represent about 10 per cent. of the total area. The method of mining is to put in a 7-foot heading and then stope holes at the bottom, which is 20 feet from the ceiling. Owing to the stratified nature of the ground the powder seems to spread and two of these holes will break 40 feet of face. In the underground tramming mules are employed. The cars are loaded on to the cage, which is automatically dumped at the surface.

The ore of this mine is low grade, having a 2 per cent. sphalerite content and the lead content varies between .25 to .1 of the total concentrates.

As a rule, the mills are quite rough, but this can be explained by the fact that the conditions of the ore bodies do not lend themselves to experimental work, for in the mines which need refined concentrating the margin of profits is very small, and in the pockety deposits the ore is so rich that the operators are often content with a very rough extraction.

The Concentration of Joplin Ores.—To the visitor in the Joplin district, the many different methods and machines in use for concentration are very likely to prove confusing. Hardly any two mills are alike, and the practice is very dissimilar. The ores of Joplin are very different in concentrating properties. Until recently tables were hardly used, but now they have reached a point where operators believe that fines of any of the ores can be treated successfully, but this is not the case. As a rule, there is much carelessness in the recovery of fines on the tables. A great number of mills have no adequate settling apparatus, and a great deal of the rich slimes are carried away in the water which is used to drive the tailings to launders' elevators. In other cases, to qualify the statement that all fines cannot be treated successfully on tables, it may be stated that there is a class of ores high in iron, which settles so readily in the settlers and de-waterers that the concentrate produced is unmarketable.

The practice in Joplin at present is against fine grinding, mainly on account of the fact that there are very few mills which are able to handle the fines successfully.*

ORE SELLING.

The producer is paid by the ton of concentrate, all ore being sold in that form. The price is based on a sliding scale. Thus for sphalerite the "basis" is 60 per cent. (theoret. 67 per cent.), and for galena concentrate 80 per cent. (theoret. 87 per cent.) metallic lead. A price will be bid for 60 per cent. zinc concentrate which will become the "base

*See Engineering and Mining Journal, April 29th, 1911.

price" and additions or subtractions will be made to this price for concentrate going above or falling below a certain standard.

For example, $1.00 is paid for each per cent. of zinc above 60 per cent., and $1.00 is deducted for each per cent. below this standard. Deductions are made for moisture and other undesirable qualities such as iron, bitumen, barite, fluorspar, etc. $1.00 is deducted for each per cent. of iron above 1 per cent.

The ores from the Miami camp have been penalized heavily for the amount of bitumen in the ore, and because the ore does not usually average higher than 50 per cent. zinc. Often where it is found that the penalties are heavier than necessary, the base price is increased. Often the ore sold in lump from the free ground deposits, such as hand-picked galena, is bought on a flat bid. The ore is bought in the bin and is carted away by the purchaser.

An analysis of a composite sample of Joplin zinc ore follows:*

	%
Zinc	58.26
Cadmium	00.304
Lead	0.70
Manganese	0.01
Copper	0.049
Sulphur	30.72
$CaCO_3$	1.88
Magnesium carb.	0.85
Barium sulphate	0.82
Silica	3.95
	99.773

*W. W. Peters, Analyst, Joplin, Mo.

THE CHAMPION MINE, HOUGHTON, MICH.*

By Edward Futterer, McGill University, Montreal.

The Champion mine lies in Houghton county, in the State of Michigan, on what is called the "Mineral Range" of the Keweenaw peninsula. This peninsula has been ably described by Rickard as "a backbone of uptilted beds, mostly of volcanic origin," and flanked on both sides by beds of sandstone corresponding in nature to the Potsdam sandstones of the east.

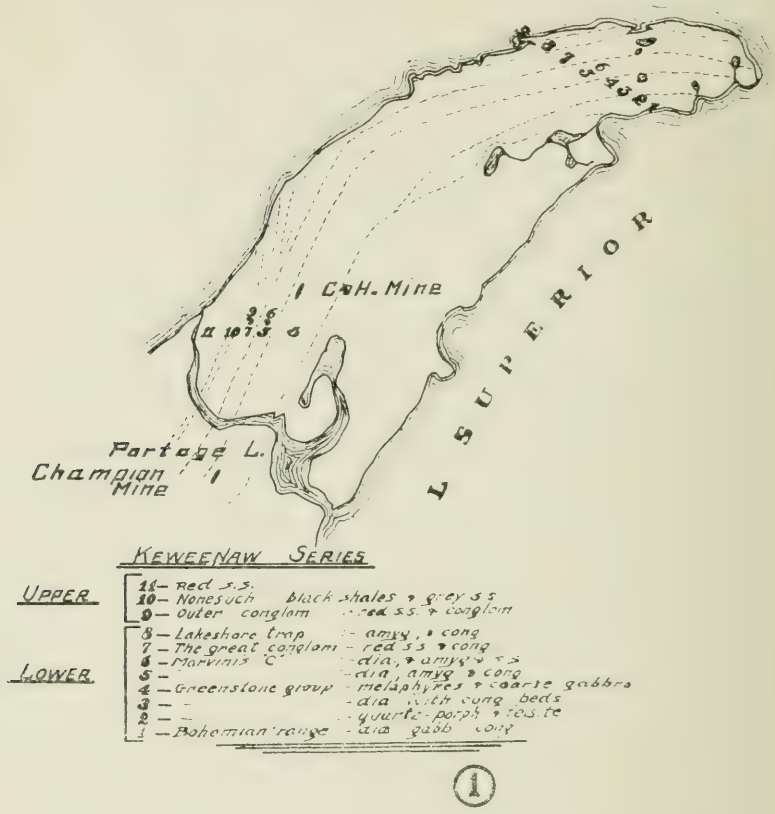
A brief outline of the geological features of this backbone will throw light on the rather peculiar underground methods in use at the Champion mine. During the Cambrian and pre-Cambrian eras, what is now the Keweenaw peninsula was the site of volcanic disturbances characterized by extrusive lava flows. These were mostly diabase, associated with porphyrites and quartz porphyrites. The igneous flows are interbedded with layers of sandstone and conglomerate . . . the latter composed principally of the rounded fragments of the more acid rocks. The copper bearing beds are the amygdaloids (in which the Champion mine is operating) and the conglomerates. The amygdules are composed of calcite, quartz, analcite, datolite, epidote, chlorite, and native copper.

The copper occurs in the shape of the amygdules, as sheet copper and as copper mass. Large pieces of the mass are extremely difficult to mine inasmuch as they cannot be drilled or sawed, but must be chiseled. This is done by hand, a good shift's work being about one sq. ft. per man.

The general strike of the mineral enriched strata ranges from N. 26 deg. E. to N. 81 deg. E. with a westward dip of from 50 to 75 deg.

An idea of the general structure of the "Mineral Range," with the geographical position of the mine, is afforded in Fig. 1.

*Prize paper, Students' Competition, 1912.


LAKE SUPERIOR
C & H. Mine
Portage L.
Champion Mine
KEWEENAW SERIES
UPPER
11 — Red s.s.
10 — Nonesuch black shales + grey s.s.
9 — Outer conglom red s.s. + conglom
LOWER
8 — Lakeshore trap amyg. + conglom
7 — The great conglom red s.s. + conglom
6 — Marvin's C amyg. + s.s.
5 — dia. + amyg. + conglom
4 — Greenstone group melaphyres + coarse gabbro
3 — dia. with conglom. beds
2 — quartz-porph. + felsite
1 — Bohemian range dia. gabbro conglom
1

THE MINE.

The Champion lode was discovered in 1900 by Dr. L. L. Hubbard in rather an interesting manner: In the Baltic, a much older mine, there is a conglomerate bed lying 110 ft. to the east of the copper-bearing amygdaloid. The amygdaloid had been weathered to such a degree that it was difficult to find an outcrop. The conglomerate being of a more stable nature was not so easily weathered. Dr. Hubbard, in prospecting over the St. Mary's Canal and Mineral Company's lands, discovered an outcrop of conglomerate strikingly similar to that at the Baltic. It was long enough to give him a line of strike. He therefore paced off 110 feet west and in a stream bed found the copper-enriched amygdaloid.

Champion Mine—Longitudinal Section.

Note.—This map represents condition of mine to May 1st, 1911.

The Champion mine is now a unit in the Copper Range Consolidated's holdings.

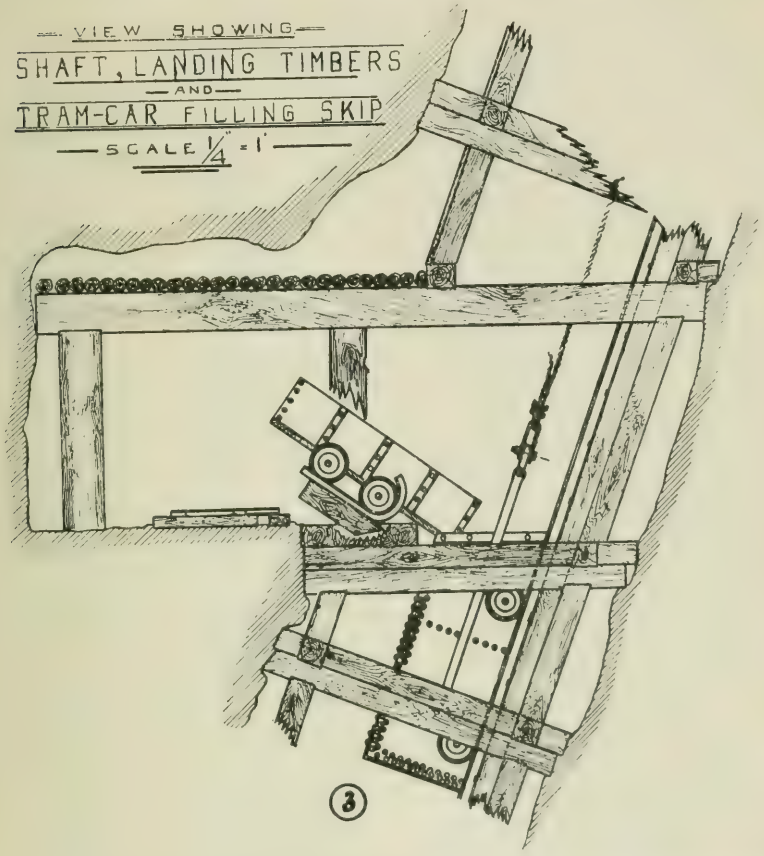
UNDERGROUND METHODS.

There are four 3-compartment shafts at intervals of about 1,000 feet on the lode. (See Fig. 2.) These have been sunk in the trap foot wall in order, so far as possible, to avoid shaft pillars. The shafts are on the angle of dip of the lode, i.e., 70 deg. to the horizontal.

The shortness of the intervals between the shafts has been a matters of serious discussion on the part of the authorities, with the result that future shafts will be sunk at longer intervals, although they are already spaced at greater distances than is the common practice of the district.

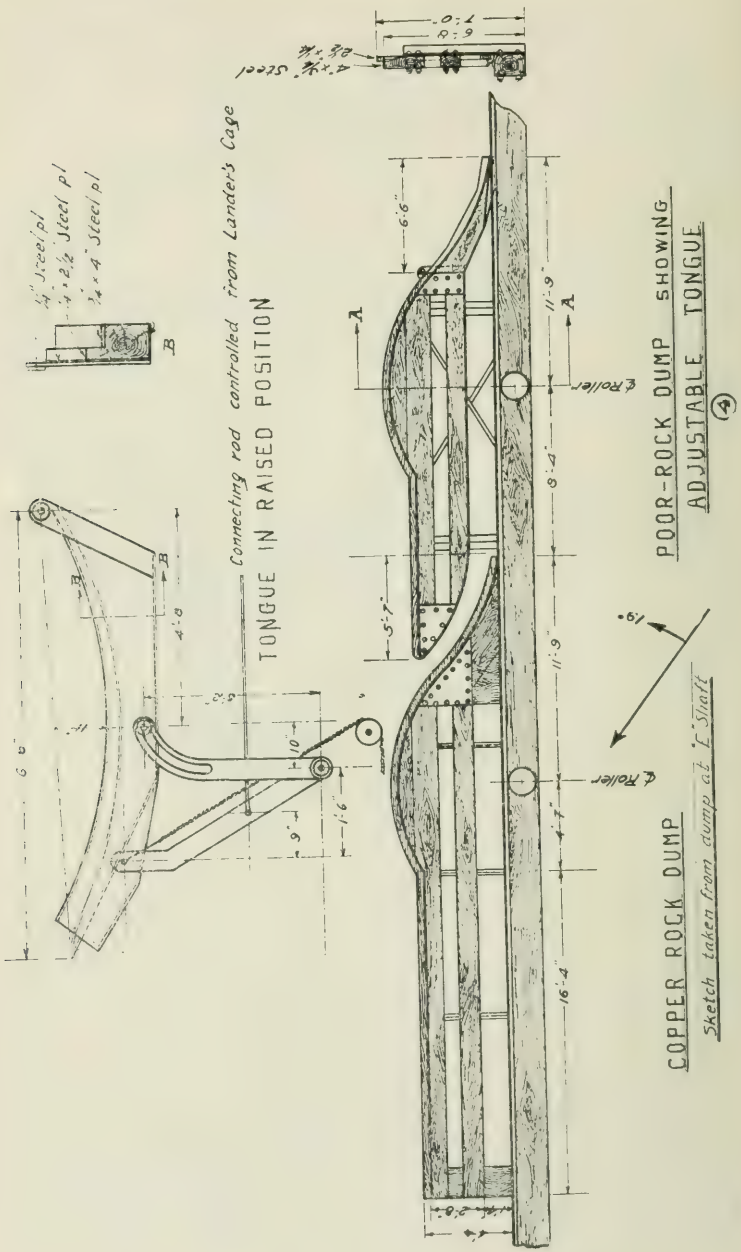
Formerly the shafts were timbered as shown in Fig. 3, cedar lagging being braced against treacherous portions of the hanging. Timber has given place to concrete, however, with the result that all the new level landings and in "D" shaft, the rail stringers and braces below the 14th level are of concrete. This, moreover, can be put in place for a surprisingly low cost. It can be reinforced with discarded cable, and the stone and sand obtained by simply placing screens over the raises into which the "poor rock" is dumped. While the writer has no figures in regard to cost of placing the concrete, yet he believes a safe estimation would be $3.50 per yard. Granting that this first cost is higher than timber, nevertheless the low cost of maintenance, its lasting qualities and safety from fire quite overbalance the low initial cost of timber which can have a life of only seven years at the most.

Because of the fact that the shafts are sunk in the foot, short crosscuts are run to the lode and the drifts started from these. The trams (which have a capacity of three tons) are pushed by hand along the drifts to 3 ft. turntables and from these to the shaft where they dump directly into 6-ton skips. A sketch of this arrangement may be seen in Fig. 3. The dumping is done entirely by "dumpers," three of whom are detailed to each shaft. This prevents the trammers from lounging about while awaiting their turn to send up the ore.



In sinking the shafts each new portion is started at the base of the ladder-way, a cut of 7 x 8 ft. horizontal section sunk for 15 feet, and the portion under the shaft bottom cut out so as to leave a pentice 10 feet thick over the heads of the workers. The muck is hoisted through the ladderway by means of a ½-ton bucket and portable hoisting machine.

The layout of shot holes in sinking is somewhat unusual as the miners object to using the centre-cut method and prefer rather to start with shallow holes along the edges perpendicular to the foot wall. The holes are made more perpendicular as they approach the opposite side.

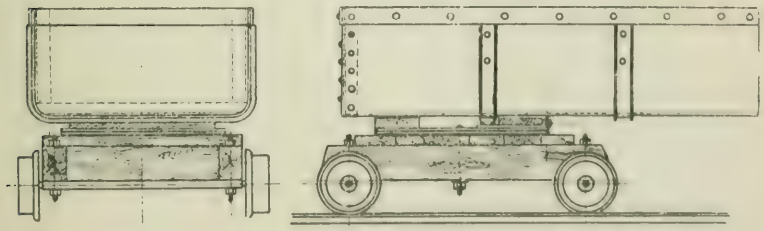

TONGUE IN RAISED POSITION
Connecting rod controlled from Lander's Cage
POOR-ROCK DUMP SHOWING
ADJUSTABLE TONGUE
(4)
COPPER ROCK DUMP
Sketch taken from dump at E. Shaft

STOPES.

Former method.—It may be of interest to present a brief description of the "old method" of stoping at the mine: Raises were made at intervals along the drifts and secondary drifts run from these 10 ft. above the levels. At intervals of 30 ft. mill holes were cut, thus leaving arches of about 20 x 10 ft. to support the hanging. The holes were strongly timbered and braced by heavy stalls. (See. Pl C.) The stopes were then started above these arches, the miners standing on the rock as they broke it.

This method was abandoned in 1908. In the first place, the enrichment of the lode is irregular and since all the rock had to be hoisted to the surface, it entailed a heavy tramming and hoisting expense. Then when it did get to the surface only about 20 per cent. of the "poor rock" could be picked out—which meant a high cost in shipping and milling. Furthermore, upon the withdrawal of the mill rock, large pieces of the hanging were likely to break off and mix with the amygdaloid, and finally there remained the question whether the pillars would sustain the creep of the hanging when the mine shall have been deepened? Judging from the fate of the Atlantic mine, the pillars would not resist this force. Hence necessity demanded a change of method.

The Dry Wall Method.—This method is carried out somewhat as follows: A drift of 8 x 12 ft. is driven ahead for a convenient distance and then, starting about 25 ft. from the shaft, is stoped out the width of the vein and 15 ft. high. The position of the permanent track having been chosen, large pieces

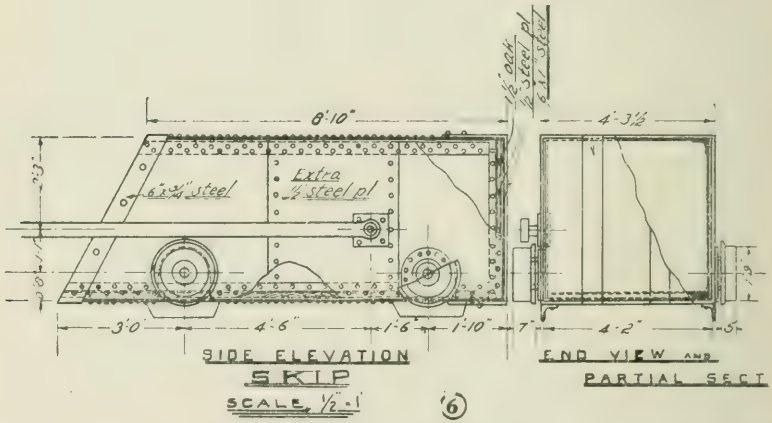


1½ TON STOPE CAR ⑤

SCALE ¾"-1'

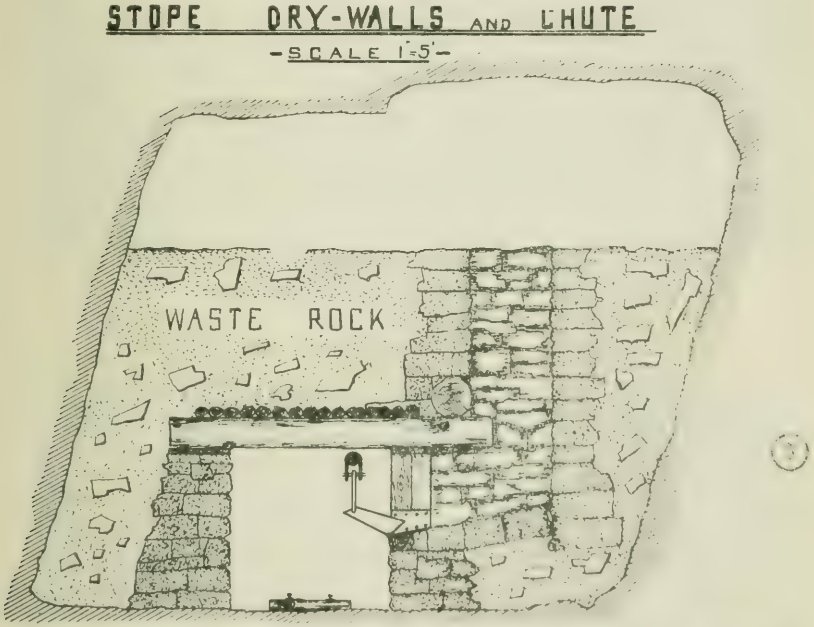
of waste are laid alongside to start the dry walls with. The dry walls are then built. One of these walls is placed as near the foot as possible, in order that the mill holes may not rise up into the hanging. The walls are 5 ft. thick at the base, 3 ft. at the top, 8 ft. high and 8 ft. apart—thus leaving an 8 x 8 ft. tramway. At every 50 feet, a space for a mill hole is left. As further material is broken down in the drift stope, the larger pieces of waste are laid alongside the track, and the fine stuff trammed back and thrown over the walls for fill.

Finally, strips 2 x 12 ft. plank, one depe, are placed along the tops of the walls and the "wall pieces," i.e., timbers not less than 20 inches diameter and 14 feet long, are laid across 5 feet apart c. to c. Over these are laid cedar and hardwood lagging. The cost of building the walls is about $5.00 per foot along the drift.



The mill holes (see Fig. 7), are 4 feet 6 inches in diameter and made of stone. In the Baltic mine, where this method of stoping originated, it was formerly the custom to line the holes with timber. It was thought that stone dry lining could not stand the terrific battering received from the falling rocks. So well have the Austrian wallers done their work in the Champion mine, however, that there has not as yet been a single case of serious damage to the mills. The walls and timbers having been put in

place, the miners break down the rock (at first carefully) on top of the lagging in successive layers of about 20 ft. thickness. As the drillmen work forward, the pickers follow, cutting into the layer, picking out the copper rock and throwing it into the small stope cars (see Fig. 5) or the mill holes as convenient and shovelling back and levelling off the poor rock behind them. The trammers remove the rock from the mills in cars holding about 3 tons each. These are run to the shaft to await the "dumpers." When one layer has been broken down, the miners go back, and, setting up on top of the "poor rock" picked from the previous layer, start another.



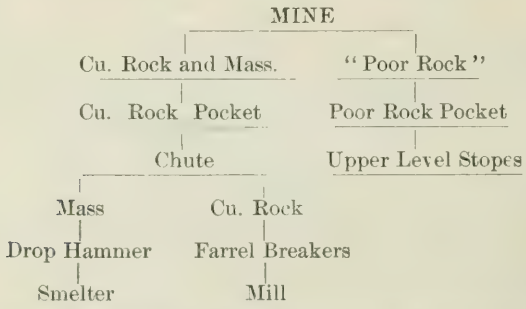
The labour efficiency of the mine is low—due, at least, in part, to the evident impossibility of putting even a large percentage of the labouring force on contract. This efficiency is still further lowered by the peculiar conditions under which the pickers work. Thus if the pickers be not "driven" by the trammer bosses they will do very little work. If they are driven, or, in other words, a larger number of cars demanded, they invariably

throw "poor rock" into the mills. This is further stimulated by rivalry between the trammer bosses, who, nevertheless, unavoidably are judged in terms of the number of skips they get to the surface. There are always two shift bosses at the mine. These men are not judged in the same terms as the trammer bosses. But two men can hardly inspect the whole mine each day. The result often is a shortage of waste rock for fill and consequent necessity of blasting it from the hanging; an extra cost for levelling this off, and also an unnecessary cost in tramming, hoisting, shipping and milling the "poor rock" thrown into the mills.

In order to minimize this evil it is probable that a larger number of shift bosses will in the future be kept on duty underground.

The Shaft House.

The shaft houses, or, as termed in the "Copper Country," rock houses, are steel structures, 96 feet from surface landing to sheave. The passage of the ore through the house is as follows:



The most interesting feature of the Champion shaft houses are the rather unique skip-dumps in use. These have been designed to dump the "poor rock" (about 7 per cent. of the total rock hoisted) into separate pockets. The dump (see Fig. 4) is merely an arrangement shaped like a miniature reversed railroad curve turned with its plane in a vertical position. The front wheels of the skip (see Fig. 6) are 5 inches broad and pass the curve, but the hind wheels being 2 inches broader run up on it, so overturning the skip.

The tongue of the upper dump, i.e., the copper rock dump, is stationary, but that of the lower dump, i.e., the "poor rock"

Plate A.—Arrangement for checking rock in chute on its way to breaker.

Plate B. Dry walls in stoping.

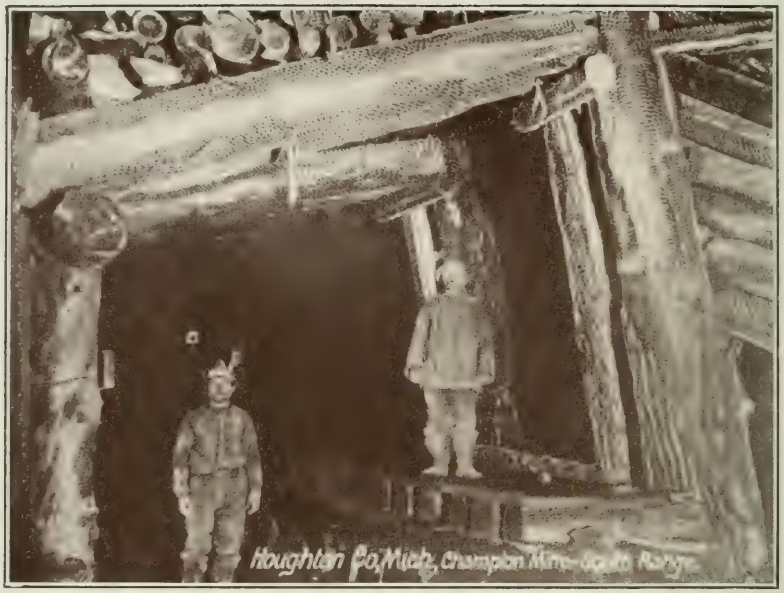


Plate C.—Timbering used in old stopes.

Plate D.—Shaft at Champion mine.

dump, can be lowered to catch the hind wheels of the skip in the same manner as the one above. This movable tongue is controlled from the lander's cage.

The poor rock is trammed out from its pocket and dumped into raises. The copper rock slides from its pockets into 32 in x 24 in. Farrell jaw breakers, of the Blake type, two of which are placed in each rock house. These crushers have each a capacity of about 150 tons per hour, each pair being driven by a 75 H.P. Nordberg single cylinder engine. The rock is broken to 4 in. size, although, no screens being used, considerable flat oversize goes into the bins.

The mass is hauled out of the chutes by means of a steam lift and conveyed under a steam drop hammer where a large percentage of the gangue is battered out of it. An idea of the method of controlling the rock in the chutes may be gleamed from (Plate A.).

The rock house expense per ton of rock stamped is:

	Per ton.
To labour	$0.0215
To maintenance, power, etc.	.0355
Total	$0.0570

HOISTS.

The four hoists at the mine are of the Nordberg conical drum, first motion type. The effective H.P., etc., are tabulated below:

	B. AND C. HOISTS	D. AND E. HOISTS
Cylinders	32 in. x 72 in.	24 in. x 60 in.
Effective H.P.	Approximate 2,00.	Approximate 1,500
Total capable lift	15½ tons from 5,000 ft.	8½ tons from 3,000 ft.
Length of drum	14 ft.	16 ft.
Large diameter of drum	18 ft. 6 in.	14 ft. 1½ in.
Small diameter of drum	12 ft. 6 in.	7 ft. 6 in.
Steam consumption	60 lbs./Eff. H.P./hr.	60 lbs./Eff. H.P. /hr.
Size of cable groves	1⅞ in.	1⅞ in.

The boilers used in connection with the hoists are of the Burt locomotive type. Attempts to economize in steam throughout Michigan, so far as hoisting is concerned, has not met with the success anticipated. The authorities at the Champion, profiting probably by the example of the Calumet and Hecla's attempts in this respect, have as yet taken no steps in this direction.

The hoisting expense in terms of the tons of rock stamped is:

	Per ton.
To labour	$0.0209
To power and maintenance	.0565
Total	$ .0774

In order that no accidents may occur because of defective cables, the following regulations are rigidly carried out:

1. The cables are examined twice a shift.
2. Six feet at the shackle is cut off and the entire cable calipered every month.
3. The rope is turned end for end every 6 months and tensile tests applied.
4. The cable is discarded if the tests run low or at any time it seems to be well worn.

The tests are carried on in a hydraulic tension machine made at the mine.

In this same machine some excellent data was collected in regard to the holding power of various clamps and clips in use. This is tabulated in part below:

NATURE OF CLAMP OR CLIP.	HOLDING POWER.
1¼" Crossby Rope Clamp on bare cable	8 tons
" " " with iron filling on cable	6 tons
Malleable iron clamp on bare cable	30 tons
" " " with cable wrapped in hemp	20 tons
" " " with Crossby Clip above	35 tons

THE MACHINE AND BLACKSMITH SHOP.

The method of drill maintenance as followed in these shops is productive of very economic results.

There are 96 Ingersoll machine drills in operation, 2 Water Leyner, and 4 Stopers. All the parts of the machines, with the exception of the unturned cylinder castings, and made at the mine. This reduces the cost of the machine by nearly half, and is also advantageous in that worn pistons can be replaced by others in stock, and so with the other parts of the drill.

The blacksmith shop is equipped with 3 mechanical drill sharpeners, each capable of handling 800 drills in 10 hours. These are simple devices, but are doing good work, the average number of drills sharpened per day in 1910 being 846.

A split die is being used in this work and is found to be superior to the older solid dies. It is made in four parts, i.e., split through the apices of the V's. For this reason it can be easily ground.

In general the cost of drill maintenance is as follows:

To new cylinders	$0.20	per	drill	per	month
Repairs and minor parts	5.27	"	"	"	"
New steel (approx.)	3.60	"	"	"	"
Steel sharpening (approx.)	2.10	"	"	"	"
Total	$11.17	"	"	"	"

COMPRESSORS.

There are two compressors in operation at the mine: one, an Ingersoll cross-compound, 2-stage condensing engine delivering 3,500 cu. ft. of air at 70-lb. pressure per minute, and the other a very large and interesting Nordberg quadruple expansion machine, known in the "Copper County" as "The Champion Compressor."

The Champion Compressor has a capacity of 9,000 cu. ft. of free air per minute compressed to 80 lbs. There are two high pressure and two low pressure air cylinders mounted in front of the four steam cylinders of the quadruple expansion engine.

*"The exhaust steam in passing from one cylinder to the other gives up part of its heat to the feed water, which circulates through four heaters placed in series and which heaters are supplied with steam from the different receivers and the low pressure exhaust. The feed water enters the heater in which the tem-

*Nordberg Mfg. Co. Circular.

perature is lowest and is gradually heated up to a temperature of 344½ deg. F., at which temperature it enters the boiler.

The engine* was designed to use at 300-lb. pressure. Three Geary water tube boilers were installed, with a Green economizer for the flue gases, but were incapable of working uniformly above 250-lb. pressure.

The cost of compression is as follows:

To labour	$0.0168	per ton of rock stamped
To power, etc.	0.0565	" " " "
Total	$0.0733	" " " "

THE MILL.

The mill is what would be called in Michigan, a "7-stamp mill." The stamps, however, are compound, Nordberg steam stamps each having a capacity of from 400 to 700 tons per 24 hours.

The mill can be divided into two sections, i.e., one section using the Hodge jig and the other the Woodbury system.

The flow-sheets of these two systems can be seen in Fig. 9.

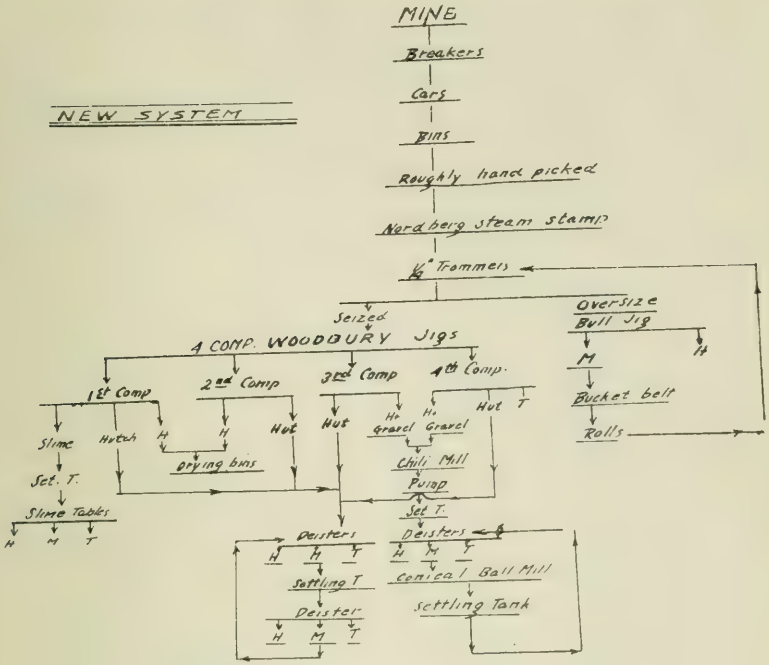
They are making an 86 per cent. extraction with the costs of labour and maintenance as follows:

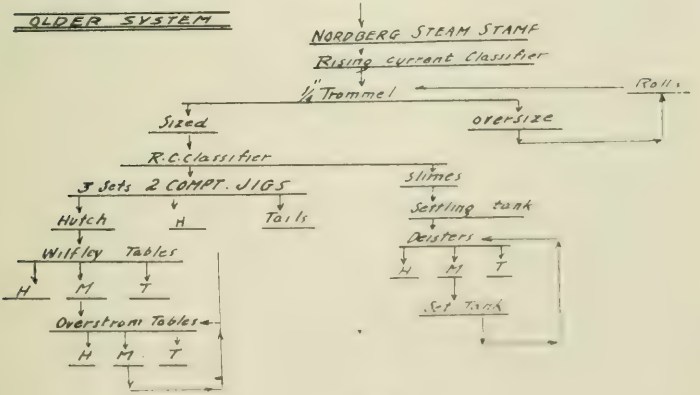
To labour	$0.0888	per ton stamped
To power and maintenance	0.1259	" " "
Total	$0.2147	" " "

SUPERINTENDENCE AND LABOUR.

The positions of authority at the mine are held by men of engineering training. The underground superintendence, however, is in the hands of Cornishmen. The workmen are Austrians, Croatians, Poles, Fins, and Cornishmen. Austrians and Croatians are employed as wall builders, and also do most of the picking. The Poles, being in general hardier men, are the trammers. The mining is entrusted to the Cornishmen and Fins. The miners do the rock breaking, stoping on company-count, drifting and shaft sinking on contract. On contract work "powder" with fuse and caps, and "sunlight" are charged up to the men, the charge for "powder" with fuse and caps being at the rate of

*For a full description see Prof. O. P. Hood's report. Vol. 12, Lake Superior Mining Institute.


NEW SYSTEM
MINE
Breakers
Cars
Bins
Roughly hand picked
Nordberg steam stamp
½" Trommels
Seized
Oversize
Bull Jig
4 COMP. WOODBURY Jigs
M
H
1st Comp
2nd Comp
3rd Comp
4th Comp.
Bucket belt
Slime
Hutch
H
Hut
T
Rolls
Drying bins
Chili Mill
Pulp
Set. T.
Slime Tables
Deisters
Settling T
Deister
Conical Ball Mill
settling tank


OLDER SYSTEM
NORDBERG STEAM STAMP
Rising current Classifier
½" Trommel
Rolls
Sized
oversize
R.C. Classifier
3 Sets 2 COMPT. JIGS
slimes
Hutch
Tails
Settling tank
Wilfley Tables
Deisters
Overstrom Tables
Set Tank

$10.00 per 50-lb. box; and of a "sunlight," 2c. per man per shift. The "powder" is 30 per cent. dynamite, worth $5.75 per box.

On the average, four miners will drift about 70 feet per month, using 16 boxes of dynamite. The contract price is $7.00 per foot run, it being required that the drift shall have a clear section of 8 x 12 ft.

In shaft sinking the contract is let to gangs of eight men—four miners and four muckers. The rock is broken by the two machines during the day and taken out on the night shift by the muckers. The section must be a clear 8 x 20 ft.

Below is a distribution of superintendence and labour in terms of the cost per ton of ore stamped:

COST OF SUPERINTENDENCE AND LABOUR PER TON FOR 1910.

Underground Superintendence and Labour.

Position	No.	Average pay/shift	Cost/ton stamped	
Mining Captain	1			
Shift Bosses	2	$ 3.53	$0.2224	
Trammer Bosses	12			
Miners on Company-count	380	2.48	0.3903	
Miners on Contract	40	3.23	0.0547	
Pickers	205	2.23	0.1936	
Trammers	225	2.23	0.2125	
Wallers	66	2.23	0.0623	
Timbermen	30	2.34	0.0270	
Sundry positions	16	2.16	0.0147	
		Total	$ 0.9865	$ 0.9865
General Manager, office force, Engineers and sundries	41		$ 0.0465	
Labor on Hoists	26	$ 1.90	0.0209	
" " Rock Houses	24	2.12	0.0215	
" " Compressors	18	2.22	0.0168	
" " Machine Shop	10	2.84	0.0120	
" " Blacksmith "	20	2.42	0.0205	
" " Carpenter "	7	3.08	0.0292	
Surface gang and Foreman	21	1.99	0.0176	
			$ 0.1641	$ 0.1641
Superintendent and Employees	101	$ 2.13	$ 0.0888	$ 0.0888

Sum total	$1.239
Total cost per ton of working expenses	1.758

Hours of Labour.—The hours of labour underground are from 7 a.m. mine time (6.30 Central time) till 4.30 p.m. (at this time the holes are fired) with 30 minutes for dinner. The cages go up at 5 p.m. On week ends only 5 hours of labour is put in by the miners on day shift and 7 hours by the others. On the Saturday night shift the miners do not report for duty.

SUMMARY OF COSTS FOR 1910.

MINING COSTS.	COST PER TON STAMPED.	
Superintendence and labour	$0.9865	
Rock house expense, including labour	0.0570	
Hoisting expense, including labour	0.0550	
Power drill expense, including compressor	0.0733	
Powder	0.1066	
Supplies	0.0736	
Total	$1.3520	$1.3520
SURFACE EXPENSES.		
Superintendence and labour	0.0325	
Supplies	0.0199	
Teaming	0.0027	
Insurance	0.0059	
Electric lights and telephones	0.0012	
Library maintenance	0.0024	
Legal and general expense	0.0016	
Purchasing department	0.0048	
Total	$0.0710	$0.0710
Transportation to mill		0.1389
Stamp mill expense		0.2147
Smelting and freight, marketing, etc.		0.2322
Taxes		0.1010
Total		$2.1098
Less Rents received		0.019
Total cost of production		$2.091
Yield of rock treated 26.62 cu. per ton at 12.74c. per ton		$3.391
Profit per ton		$1.30

The writer is greatly indebted to Mr. W. Schaet, assistant manager of the mine, and to the many foremen, all of whom he consulted without mercy.

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